

**Canadian University Research
and Teaching Resources in
Advanced Industrial Materials**

John M. McIntosh

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Centre for Resource Studies

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Foreword

This is a background study surveying the situation with regard to data on Canadian University research and teaching in Advanced Industrial Materials (AIM). It was commissioned by the Technology Policy Sector of Industry, Science and Technology, Canada (ISTC). This study examines data previously assembled by NSERC and MOSST regarding university research activity in AIM with a view to establishing its validity. In addition, trends in the age distribution of faculty engaged in materials research, in the numbers of graduate students enrolled in materials-related programs and in the development of new curricula are examined and some predictions made on the basis of this process.

Simple statistical analysis and manipulation of research data will not provide answers to policy questions. Critical evaluation and judgement based on understanding of the areas involved are also required. To this end, the opinions on many important points of a number of leaders in the AIM field have been canvassed and discussion of these forms a large part of this report.

The views expressed in this report are those of the author and not necessarily those of the Centre for Resource Studies and its sponsors, or of Industry Science and Technology Canada.

Margot J. Wojciechowski
Executive Director
Centre for Resource Studies

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The assistance and advice of the staff at ISTC helped a neophyte negotiate the Ottawa maze and avoid many pitfalls. In particular, Justyna Laurie-Lean and Carol Sequin were always cheerfully helpful.

Although grateful for all the advice, information input and help, the author accepts responsibility for the opinions expressed and conclusions reached.

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Summary

Objective

This study is a cooperative effort funded by the Technology Policy Branch of Industry, Science and Technology Canada (ISTC) and carried out by the Centre for Resource Studies at Queen's University as the principal contractor and Dr. John M. McIntosh of the University of Windsor as the principal investigator. Its objectives were to evaluate the accuracy of two earlier studies, and build on them to provide an overview of the research and teaching resources in advanced industrial materials in Canadian universities.

Method

The various data series used for the preparation of the two earlier studies - "Funding of Research in Advanced Materials and Technologies Through NSERC" and "Advanced Industrial Materials Canadian Sourcebook 1988" (MOSST) - have been examined, analyzed and merged in this study into one dataset. This dataset (the "CRS composite list") reflects the situation as reported in 1987.

To assess the accuracy of the resulting CRS composite list, four steps were taken:

1. A sample of 118 people from the composite list received a questionnaire requesting verification of the information on them and their research.
2. Every university department identified in the list was asked to verify the names of all faculty involved in materials research in 1987 and add corrections where necessary. Information was also requested about the current numbers of graduate students involved in materials-related research, aggregated by program (M.Sc. or Ph.D.) and by students' origin (Canadian or Visa).
3. Interviews were held with a number of individuals in the sample to obtain opinions on opportunities and problems in materials research in Canada.

4. Biographic data were collected on as many faculty involved in advanced industrial materials research and teaching as possible, with a view to analyzing trends in faculty age and nationality.

Findings

During this process, a number of important problems were identified and observations made.

Most of the faculty identified by the NSERC study are correctly identified as being in materials research, especially after those identified as "being peripherally" involved are removed. However, many additional people and projects in the field were omitted.

The information obtained by the MOSST survey is useful only as a supplement to the NSERC list.

The CRS composite list is also very incomplete. Nevertheless, it can form a basis for generation of future lists. Such lists should be based on people rather than project titles. Initially generated lists should be reviewed by acknowledged leaders in the materials area for additions and modifications, but it must be accepted that the nature of the field ensures that no list will ever be 100 percent accurate.

Future information gathering should utilize interviews in place of questionnaires as much as possible. The information obtained in this manner is much more useful.

There is difficulty in defining the area of "Advanced Industrial Materials" with sufficient rigour to allow unambiguous inclusion or exclusion of projects and faculty. Use of properties-specific classifications, as in the U.S. National Academy of Sciences listings, is a possible partial solution. The adjectives "advanced" and "industrial" should be deleted and attention addressed to the materials area in general.

Cooperative research efforts involving industry and university personnel frequently arise from personal contacts which predate the research interactions. Maximizing the chances for such contacts is highly beneficial to initiation and success of such joint projects.

There are several universities in Canada where materials research is becoming a central focus. These may involve one area (e.g. polymers) or be highly interdisciplinary and cut across traditional materials boundaries. Departments of materials science, until now heavily biased toward metallurgy, are broadening their bases of activities.

Granting council policies can have a strong positive or negative influence on the ability and desire of faculty to carry out interdisciplinary research. This potential should be considered in setting these policies.

The age distribution of materials-related faculty in Canadian universities is very similar to that of engineering faculty in general. Many of the most productive and highest-funded faculty are nearing retirement age. The percentage of Canadian faculty in the younger age groups is increasing, but the absolute number of faculty in this group is declining rapidly. Unless special remedial efforts are made, the consequence of these facts may be a sudden decline in the number of materials scientists and in the number of proposals and total funding support for the area within Canadian universities in the next decade.

The curricula used to educate undergraduate engineering students in materials science are generally very out of date. A concerted effort is required to remedy this.

The demand for students with materials science training is large. This is true in both industry and universities. Canadian students form a larger percentage of those currently enrolled in graduate materials programs than is the case generally for engineering and science students. A higher percentage of materials-related engineering students are enrolled in PhD programs than is the norm for other engineering areas.

1. Introduction

Objectives

The objectives of the study were to

- document and analyze the research and teaching resources in advanced industrial materials (AIM) at Canadian universities;
- identify strengths and weaknesses and establish a framework for monitoring future trends in AIM resources in Canadian universities;
- provide an information base which can be used to evaluate the adequacy of these resources;
- learn from the successes and failures of previous examinations of this field of research.

Background

The area of advanced industrial materials has been identified as one of the strategic technologies of special importance to Canada's future. In 1987 the Ministry of State for Science and Technology (MOSST) undertook the assembly of information for "The Advanced Industrial Materials 1988 Canadian Sourcebook", a compilation of all companies, research organizations and individuals at Canadian universities who were involved in advanced industrial materials research.¹ At the same time, the Natural Sciences and Engineering Research Council (NSERC), the principal federal funding agency for Canadian academic scientific and engineering research, undertook a review of its funding of the same research area in Canadian universities.² It

must be emphasized that NSERC did not claim that its study represented the overall AIM research situation at Canadian universities, but only the research supported by NSERC. Nevertheless, as NSERC is the main supporter of university research, and few individuals who are active in areas supported by NSERC are not supported to some degree by this agency, the data were generally viewed as a reasonably complete audit of the area.

The pictures presented by the two studies were radically different. NSERC reported support to over 650 projects totalling in excess of \$33 million. At the same time, MOSST reported a university funding total of only \$20 million from *all* sources (including NSERC). The disparity between the results of the two studies suggested the need for an assessment of the validity of the two lists. In addition, some important information (e.g. manpower, curricula) was lacking. This report attempts to remedy these deficiencies in the following ways:

- by assessing the methodology of the data-gathering procedure of the two 1987 studies. The techniques used by NSERC and MOSST are described and analyzed with reference to how the process may be improved;
- by presenting some revised estimates of the level of university financial support for AIM research, by assessment of the available data and addition of new information gathered by in depth examination of a selected sample of that data;
- by presenting, for the first time, some information on Canadian university manpower resources in AIM. These will include various aspects of faculty currently active in AIM research, the current situation with regard to graduate student enrollments, and the impact of

¹ "The Advanced Industrial Materials 1988 Canadian Sourcebook", Ministry of State for Science and Technology, 1988.

² J. Pocock, "Funding of Research in Advanced Materials and Technologies through NSERC, 1984/85-1987/88", Natural Sciences and Engineering Research Council of Canada, 1988.

both on the future situation for university-based materials research;

- on the basis of opinions gathered from individuals who are active in the area, recommendations are made on how this sort of data-gathering exercise can be improved.

The current study (referred to throughout as the CRS study to distinguish it from the NSERC and MOSST studies) is a cooperative effort funded by the Technology Policy Branch of Industry, Science and Technology Canada (ISTC) (the successor to MOSST), and carried out by the Centre for Resource Studies (CRS) at Queen's University as the principal contractor and Dr. John M. McIntosh of the University of Windsor as the principal investigator.

Scope

Location

The CRS study was restricted to materials research carried out at Canadian universities and university-affiliated research institutes. Technical colleges and government, industrial or private laboratories were excluded.

Research Areas

The ten areas of AIM defined and used by NSERC in its study were initially adopted as defining the scope of this CRS study. However, during the study, the usefulness of this list came into question; the latter stages of this report address this fundamental question in more detail. The ten areas, as defined by NSERC, are shown in Table 1.

In addition, an eleventh area (DES = end product design using advanced materials) was addressed in a peripheral way.

The NSERC definitions were adopted for use in the CRS study with much trepidation. The difficulties involved in defining such an area as amorphous as AIM had been noted in many previous studies.³

³ *Ibid.*

Table 1

Codes and definitions used by NSERC

Code	Definition
CER	ceramics, glass and refractories
COA	coatings, surfaces and interfaces
COM	composites and compound materials
FIB	fibre optic and laser materials and technologies
LIQ	liquid crystal materials
MET	metals and alloys
PHO	photovoltaic materials
POL	polymeric materials and processes
SEM	semiconductor materials and technologies
ROB	robotics and systems materials and technologies

A complete summary of previous attempts was provided in the NSERC study. A recent US study on materials research carried out by the National Academy of Sciences largely abandoned the NSERC type of materials-specific definition in favour of a properties-specific method.⁴

Human Resources

In the area of human resources, three areas were addressed:

- number and selected biographical data of university researchers identified as being active in AIM research. These were defined as people in positions eligible to receive NSERC operating support;
- number of graduate students (MSc and PhD) involved in AIM research. A considerable body of opinion suggesting that MSc students were important to the needs of industry led us to include MSc students in later stages of the data collection in this study;

⁴ *Materials Science and Engineering for the 1990s*, National Academy Press, Washington, D.C., 1989.

- an assessment of the state of integration of AIM advances into the teaching curricula of *related* departments, especially at the undergraduate level. Such integration is crucial for rapid and successful transfer of university research results into the marketplace.

Other Studies

Interest on the part of government and industry in the general area of materials research and development is intense. During the CRS study, it became clear that university science and engineering departments are being inundated with requests for information on AIM and many other research areas, from both government and private organizations. An indicative, but not comprehensive, list of concurrent materials-related surveys includes those being carried out by the Technical University of Nova Scotia (TUNS), ISTC (on activity in superconductivity), Saskatchewan Research Council (on AIM activity in the province of Saskatchewan), and the Royal Society of Canada, which is conducting a pilot project on materials research as part of a program to evaluate several areas of scientific research in Canada.

In addition, the Technology Policy branch of ISTC has a concurrently funded study of AIM research in industry, and the Programs branch has a survey of the AIM component of university agencies established to operate at the university-industry interface. While in theory this does not have a direct impact upon the constituency for this report, in many cases the same faculty were being simultaneously canvassed by more than one agency. As a consequence of the proliferation of AIM-related studies, some resistance on the part of faculty to taking part in this study was met.

Report Organization

The report is presented in five general sections. Following this Introduction, Chapter 2 presents the 1987 NSERC and MOSST data, and analysis of them from several points of view. Chapter 3 presents the methodology which was used during the course of this study to evaluate and supplement the earlier data, and the results obtained. Chapter 4 is concerned with qualitative aspects of the information gathered in the course of interviews, and Chapter 5 presents conclusions and recommendations.

2. Existing Statistics: The 1987 Lists

Sources

The data available at the outset of this study lay in the two 1987 compilations previously mentioned. The complete data are available on request. Summaries of the data in tabular and graphical form are shown in Tables 2 to 10 and Figures 1 to 7. Neither of these datasets included any information on human and manpower resources.

The NSERC Data

An analysis of the data compiled by NSERC is shown in Figures 1 to 6 and summarized in Table 2.

Table 2

NSERC data summary

Total number of individuals identified	551
Total number of projects identified	657
Total number of granted dollars (000)	\$33,733

An understanding of the methodology used by NSERC to compile its statistics is important. A set of codes (Table 1) was constructed to describe the various areas of AIM activity, and a list of the titles of all grants awarded in the 1987/88 granting year was searched manually for projects which fit these codes. As a method for developing a primary data source for a comprehensive inventory of university AIM research, this procedure has several deficiencies:

- Areas that are primarily or exclusively funded by other agencies (e.g. MRC for biomaterials) are either underrepresented or absent. This

was not a problem for NSERC since it was surveying only its own contribution to the area.

- Decisions made when the NSERC list of codes was constructed led to the exclusion of certain materials-related areas. For example, the absence of codes which clearly included concrete or magnetic materials resulted in a significant understatement of advanced materials research in these areas. Whether these were excluded by design or by accident, the result was an incomplete list.
- Inclusion or exclusion of a project from the NSERC study rested on interpretation of grant application information by an NSERC employee who was not an AIM researcher and who did not possess expertise in all areas of materials research. This led to some unwarranted entries and exclusions in the NSERC study. As an example, applications containing the word "organometallic" were apparently included in the "composites" category, but few, if any, of such projects were actually materials-related.
- Many of the entries (32 percent) in the NSERC list were designated as "partially, potentially or peripherally related" to AIM.⁵ However, no attempt to determine any actual connection with AIM research had been made; the designation itself suggests doubt that such projects are truly materials-related. Despite this, the funding for these projects was included in the NSERC totals, which seems to assume that they were in fact a valid part of materials research. A small sampling of the projects included in this category of the NSERC study suggested that many inclusions were spurious.

⁵ Pocock, J., "Funding of Research in Advanced Materials".

Figures 1 to 3 give the analysis of the NSERC data by grant type. In this description, the Operating Grants Program (OGP) includes equipment and infrastructure grants as well as operating grants. Data for University Research Fellows are included in this category. The Strategic Grants (STR) include operating and equipment grants given under this program. The University-Industry Program (UIP) includes the Cooperative Research & Development as well as Industrial Research Chairs established under this program. Figure 4 shows that the largest amount of money was put into the "semiconductor" and "metals" codes (SEM and MET), while robotics (ROB) had the largest number of grantees.

Examination of Figures 2 and 3 shows that, in all these program types, over 25 percent of the number of grants, the number of funding dollars and the number of people funded were classified as "peripheral" by NSERC. When the same data are considered by code (Figures 4 and 5), it is clear that the degree of uncertainty is very low in some areas (CER, COA, LIQ) but very high in others. The case of robotics (ROB) stands out in this analysis.

As noted previously, NSERC included the projects classed as "peripheral" in its totals. Such projects represent a considerable part of the total, and it would seem prudent to verify that these are truly materials-related. If a significant percentage are unrelated to materials, this would lead to a significant overstatement of AIM research activity in the NSERC data.

The MOSST Data

The MOSST study relied on responses by individuals to a questionnaire sent out to a list of university faculty which was based on the NSERC study and supplemented by individuals suggested by Deans of Engineering. Inclusion in the MOSST dataset was automatic if a questionnaire was returned, even if the data supplied regarding funding (amount and/or source) were incomplete. The questionnaire was in two parts. The first requested titles for projects underway in the materials area, and funding amounts and source. The second part was a complex chart which attempted to classify the projects into subject areas. *Unfortunately, the NSERC codes and the MOSST classifications were not comparable, and analysis of the data in the same*

manner as that presented for the NSERC data is not possible without many questionable assumptions. However, the summarizing data shown in Table 3 have been derived from detailed consideration of the MOSST data.

Three major factors cast doubt on the validity of the dataset resulting from the MOSST questionnaire:

- No information is available regarding the effectiveness of the dissemination of the questionnaire. How many of the university faculty actually received the questionnaires sent to them is not known.
- As will be seen from the results of the CRS sample survey, many faculty who did receive the MOSST questionnaire and who were involved in materials research ignored the request for information, for one reason or another.
- The highly competitive situation in university research funding frequently leads researchers to attempt to classify their work in a way that fits as many categories as possible in order to qualify for a maximum amount of support.

In the summarized data (Table 3), the first two factors would cause a significant understatement of AIM research activity, whereas the third factor would counteract this to some undetermined extent.

The Combined Data

Table 4 indicates that there were a great many areas in which the findings of the two lists differed. This casts doubt on the validity of the earlier surveys, and complicates the process of combining the two lists.

Combining the two datasets afforded the CRS "composite list", summarized in Table 5 and shown in full in Appendix A. In generating this list, major difficulties arose due to the following information conflicts:

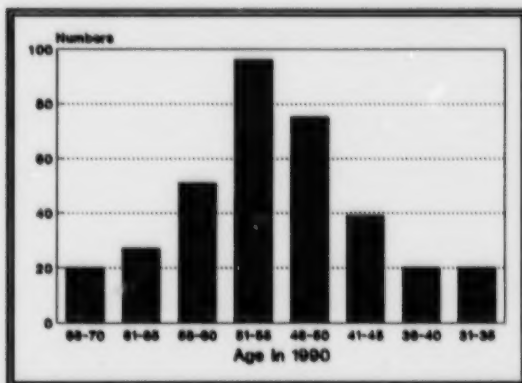


Figure 1. NSERC data by grant type
Source: Appendix D Table 1

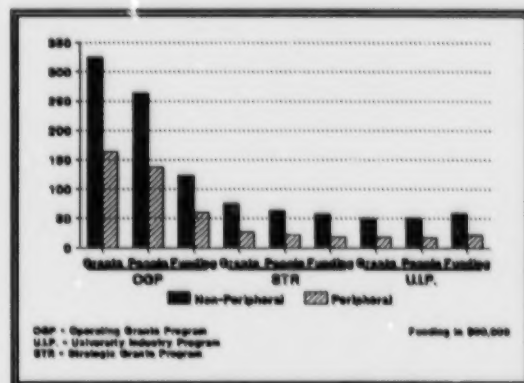


Figure 2. Peripheral grants by grant type
Source: Appendix D Table 2

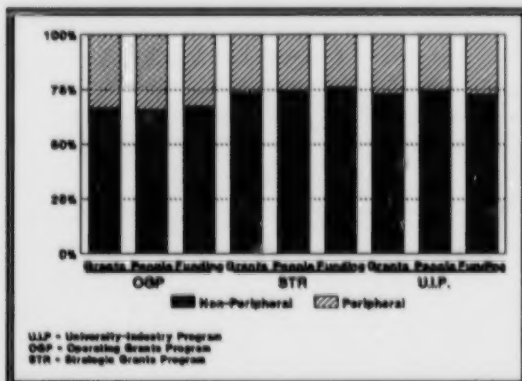


Figure 3. Peripheral grants by grant type
Source: Appendix D Table 3

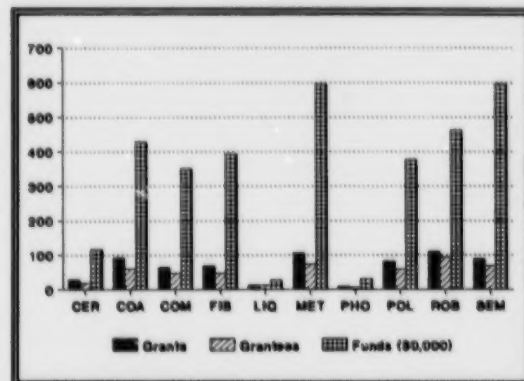


Figure 4. NSERC data by grant code
Source: Appendix D Table 4

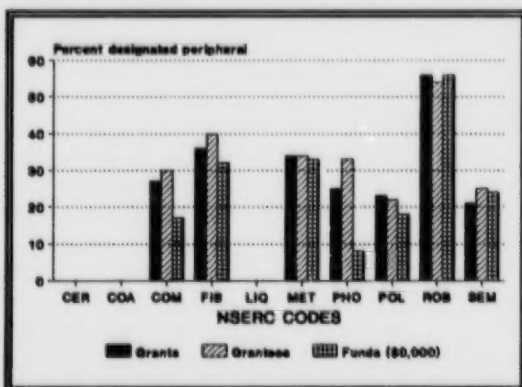


Figure 5. Peripheral grants by grant code
Source: Appendix D Table 5

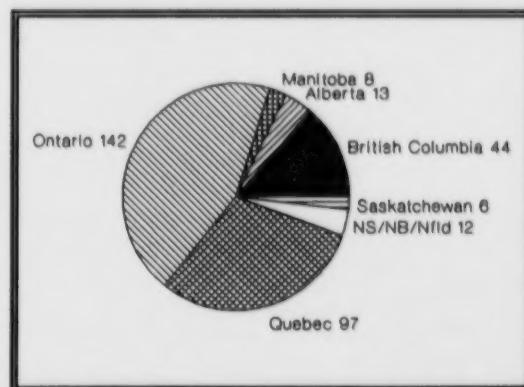


Figure 6. Geographic distribution of NSERC "AIM" funds
Source: Appendix D Table 6

Table 3

MOSST data summary

Total number of <i>projects</i> identified	383
Total number of <i>people</i> identified	209
Total number of granted dollars (000)	\$20,510*
Number of projects claiming some NSERC funding	256
Total funding (NSERC + other) for these projects	14,248

Source: "The Advanced Industrial Materials 1988 Canadian Sourcebook", Ministry of State for Science and Technology, 1988.

* data in source database incomplete

Table 4

Discrepancies identified

Number of people identified by NSERC but not MOSST	388
Number of projects directed by these people	503
Total NSERC funding of these projects (000)	\$26,003
Number of these projects classed as "peripheral"	173
NSERC funding of "non-peripheral" projects (000)	\$18,057
Number of people identified by MOSST but not by NSERC	108
Number of people identified by MOSST but not by NSERC who claimed NSERC funding for AIM projects	88
Amount of NSERC funding claimed for projects directed by these people (000)	\$1,980*

* Data obtained from NSERC master grant list

Table 5

Combined data from NSERC and MOSST studies

A. Projects	
Number of AIM projects identified by NSERC	646
Number of AIM projects identified by MOSST	370
Total	1016
B. People	
Number of people identified <i>only</i> by NSERC	371
Number of people identified <i>only</i> by MOSST	95
Number of people identified <i>both</i> by MOSST & NSERC	107
Total number of people identified as directing AIM research	573
Funding claimed for these projects (000)	\$51,884
Number of Canadian universities involved	45

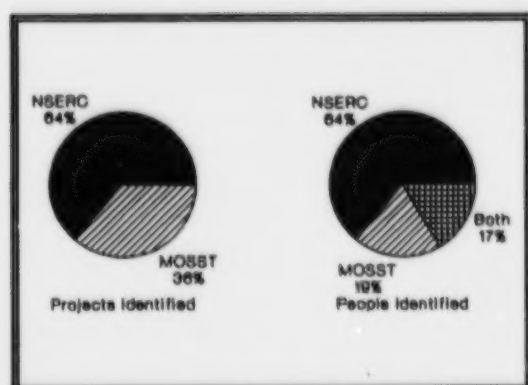


Figure 7. Data source - projects & people

- MOSST did not request the "funded grant title". It became clear in the course of the CRS study that many researchers provided MOSST with titles to their work that were different from those they had provided to NSERC.
- NSERC data provided only the amount of funding provided by that agency. Therefore, projects with additional financial support from other sources would not show the same total support in the two datasets.
- MOSST did not request the funding information on an annual basis. In many cases, the information supplied represented funding for an unknown number of years. The NSERC funding data were annual figures.
- NSERC requires that applicants give departmental designations to their university affiliations, and their data were stated in these terms. Institutes within universities are not identified. The MOSST data, on the other hand, cited many individuals in institutes within the universities. The difficulties this caused can be appreciated when the data in Appendix A are examined. Several faculty members are shown in different departments and institutes, depending upon where the data originated. The data in Appendix A are sorted first by university and second by name of faculty member.

As an example of the difficulties encountered in constructing the CRS composite list (Appendix A), it can be noted that, in several cases, the same individuals were identified in both 1987 studies as directing AIM-related projects, but there was no similarity in either project titles or funding levels between the two lists. Therefore, in attempting to eliminate duplicate entries from the composite list, considerable caution was exercised unless the titles were identical or nearly so. For this reason, the composite list, prepared early in the course of this study, was suspected to contain many unidentified duplicate entries, and this suspicion was confirmed during the data evaluation stage (Chapter 3). It is clear that the numbers shown in the composite list are significant overstatements of the actual situation.

While projects are inherently difficult to differentiate, people are not. Thus the composite list was constructed using all the unique names at each university in the two lists as the primary criterion. The dataset obtained when the NSERC and MOSST data were melded in this fashion was then edited to remove obvious duplications. This combined list of people was then used as the basis of the CRS sample survey which is outlined in Chapter 3.

It is crucial to the understanding of this report to recognize that duplicate entries can be eliminated from the composite list, but, without total reexamination of the NSERC master database, individuals and projects which were not selected for inclusion in the NSERC dataset cannot be recovered.

In other words, given the methodology of this study, it was possible to reduce the errors of overstatement due to duplication, but nothing could be done about understatement due to the omission of people or projects in the earlier studies.

3. NSERC and MOSST Data Evaluation: CRS Methods & Results

General Methodology

In order to evaluate the validity of the existing data on research activity and funding, and to gather information on the human resources aspect of AIM research, the following four steps were taken.

1. Information was solicited by mail from all university departments identified in the composite list.
2. Information was solicited by mail from a sample of the individuals identified in the composite list.
3. Interviews with some of the individuals comprising the sample were conducted at their institutions.
4. Some biographical information on the individuals identified in the composite list was gathered from a number of sources, with a view to arriving at some conclusions regarding future availability of human resources.

These four steps are referred to in the following pages as the "Student Data", "Research Data", "Interviews" and "Human Resource Data" respectively. The objectives and results of each of these processes are described in the following sections.

Student Data

In order to obtain information on the numbers of students undertaking graduate work in the AIM area, a letter was sent to every department identified in the composite list as having faculty involved in AIM research. This letter requested verification and updating of the names of faculty members who were involved in materials-related research; information on the numbers of students enrolled in

graduate programs which might be considered AIM-related; and information on the percentage of these students who were in Canada on student visas. The results are summarized in Tables 6 and 7. Information was sought on both PhD and MSc students, since both are important components of the highly qualified human resource cadre.

Information was also requested initially on the *numbers* of post-doctoral fellows and research associates and the *names* of graduate students and their thesis titles. This request met with resistance from most departments as it involved considerable amount of work. (This suggests this information is not routinely assembled by some departments.) Therefore, although some data of this type were obtained, the questionnaire was modified to request only *numbers* of students and the information was much more rapidly obtained in this format. A copy of this letter is shown in Appendix B.

A reminder letter was sent to each non-responding department after two months. This resulted in many more responses.

Several caveats regarding the data shown in Tables 6 and 7 must be noted. A majority (72 percent) of the engineering PhD students claimed in Table 7 were identified in just 14 departments in 9 universities, of the total of the 86 engineering departments canvassed. Of these, 4 electrical engineering departments alone claimed to have 93 materials-related PhD students and 4 metallurgy or related departments claimed 76 AIM graduate students.

The data were supplied by the department chairman or someone designated by him/her. The care that was exercised by these individuals in determining which students and faculty are actually involved in materials research and their interpretation of the term "Advanced Industrial Materials" appear to have varied widely. In many cases, the numbers supplied appear to represent the total faculty (Table 6) and graduate student numbers (Table 7) without regard to their involvement in

Table 6

Analysis of responses to "student letter"

Engineering departments canvassed	84
Science departments canvassed	78
Total departments canvassed	168 ^a
Responses (response rate 70 percent)	115
Faculty originally identified ^b	431
Total number of faculty originally identified as being involved in AIM (all departments)	581
Faculty Data	
<i>Originally-identified faculty deleted</i>	
Science departments	28
Engineering departments	39
Total	67
<i>New faculty added</i>	
in science departments	47
in engineering departments	69
Total	116

^a Includes 6 Business Departments.^b Number of faculty members on the original NSERC and MOSST lists and identified as AIM researchers by departments that responded to the CRS enquiry.

Table 7

Student data

	MSc	MSc (Visa)	PhD	PhD (Visa)
Overall	443	166	612	241
Science	128	47	239	95
Engineering	315	119	373	146
	% Visa		% Visa	
	% MSc	% PhD	MSc	PhD
Overall	42	58	37	39
Science	35	65	37	40
Engineering	46	54	38	39

AIM. It is the opinion of this author that, when individual researchers are indicated to be active in materials research by a person other than the researcher, the information is often questionable since the path of least resistance frequently is to accept the list presented. There is a natural tendency on the part of department officials to have as many of their faculty included in as many categories as possible, to enhance the status of the department.

Finally, although additions to the faculty researchers list drawn up by CRS were requested to reflect only the 1987 situation, information gathered during the interview process indicates that this time constraint was largely ignored. Frequent reference to the Networks of Centres of Excellence program, which did not come into being until 1989, support this conclusion.

Research Data

Data Collection

The sample for validation of the data in the composite list (Table 8) was selected to represent a sample diverse in terms of geography (Figure 6), size of AIM activity and funding. No attempt was made to select or reject entries on the basis of perceived area of AIM, amount of claimed funding, or source of the information (MOSST or NSERC data).

Letters were sent to the 118 people selected by CRS from the composite list. The letters listed the project titles and funding information which was present in the "composite list" under their name, and each person was asked to correct the data by

- deleting all entries which, in the judgement of the researcher involved, were not really materials-related;
- deleting entries which were not actually funded in the period 1987/88;
- correcting the funding amounts shown and, in particular, ensuring that the amounts shown were annualized figures;

Table 8

The mail sample

	No. of Projects	No. of People	No. of Locations	Funding (\$000)
Total ^a	306 (30) ^b	118 (19) ^b	15 (33) ^b	20,424 (39) ^b
MOSST only	120	53	14	7,751
NSERC only	150 (12) ^c	85	15	11,062 (2,358) ^c
Both	36	12	5	1,611

^a Some people were identified in both data sets but for different projects.

^b Values in parentheses represent percentages of total shown in combined list.

^c For projects designated by NSERC as "peripheral".

- classifying the projects according to the codes used by NSERC;
- providing a breakdown of the source of research funds, aggregated by the categories NSERC, Industry and Other;
- adding the titles of any topics which were funded in the 1987/88 time period and which were not shown in the list;
- providing an estimate of the change in the amount of their materials-related funding during the intervening two years.

A sample letter is shown in Appendix B. After five weeks, a reminder letter was sent to all those who had not responded. A copy of this letter is also shown in Appendix B.

Of the 118 individuals canvassed, 87 responses were received. The results are summarized in Table 9. The response rate (73 percent) was excellent and lends some extra credence to the conclusions based on the data gathered. Some of the non-respondents were involved in projects whose titles appeared to be materials-related, but some may not consider their work to be in this area. In the table, some attempt to account for this has been made and is clearly indicated.

In Table 9, projects labelled "duplicates" are those that the respondents indicated were the same work under two different titles.

Initial Conclusions and Comments

Analysis of the misidentified projects (i.e. those projects identified as not AIM) shows that there are examples in all ten classification areas. By far the largest number of errors were found in "Robotics" where 10 errors were identified. Five of these projects (50 percent) had been classified by NSERC as being "only peripherally related to AIM". In addition, as indicated in Table 10, the 50 percent misidentification also applies to the overall situation. The percentage of the total funding designated as peripheral which was incorrect was even higher (57 percent). The funding reported for these misidentified projects represents a significant part of the overall NSERC funding of the sample and suggests a substantial overstatement in the claimed total NSERC funding for AIM research. In the sample, 58 percent of projects classified by NSERC as peripheral were incorrectly identified.

If the NSERC data are taken as being approximately 85 percent correct in the people it identifies, it can be seen that MOSST missed approximately 50 percent of this group of materials researchers. Because the NSERC data are incomplete, the only real use for the MOSST data is as an addendum to expand the information base beyond those projects and individuals funded by NSERC. The incomplete nature of the MOSST data is underlined by examination of the reported activities in polymer chemistry centred at École Polytechnique and McGill University. The 19 McGill researchers were omitted entirely.

It is not unexpected that few projects were identified by CRS as "misidentified" in the MOSST data, since the researchers themselves were respon-

Table 9

Analysis of responses to research letter

A: Overall	Number	Response Rate (%)
Responses received	87	73
Projects covered	264	86
	\$000	
Total funding claimed for projects covered	16,338	80
B: Discrepancies and their Sources	Number	Funding (\$000)
<i>Deletions</i>		
Projects identified as <i>not</i> materials-related		
(a) by respondents	25	1,836
(b) by the author of this report	9	396
Total	34	2,232
Number of people directing these 34 deleted projects	29	
Duplicate projects and funding identified by respondents	12	822
Total Errors in Sample	46	3,054
As percent of letters sent out: $46/360 = 15\%$		
As percent of responses: $46/264 = 17\%$		
<i>Additions</i>		
Additional funding claimed for projects <i>already identified</i>		277
Additional projects and funding identified by respondents	29	1,166
Net Decrease in Funding (in sample)		1,161
Percent total in sample - $1661/20424^a = 8\%$		
Percent of those responding - $1661/16338^b = 10\%$		

^a See Table 8.^b See total funding above.

sible for supplying the original data to MOSST and "verifying" it for CRS.

Sources of Funding

As noted, the CRS questionnaire requested information regarding the source of funds for the identified projects. Data were requested in the form of the percent contributions by NSERC, Industry and "Other" (primarily other government agencies and granting bodies, both federal and provincial). Since many of the projects had originally been identified

by NSERC, it is not surprising that most of the CRS responses indicated NSERC as a major source of funds. Nevertheless, significant contributions to the funding totals were made by "Industry" and "Other". Of those projects which were single-source funded, NSERC funded 104 projects with a total value of \$5,173,000; industry funded 28 projects with a value of \$1,226,000; and "Other" sources funded 30 projects with a funding total of \$2,186,000. An attempt was made to correlate the size of the total claimed project funding with the source of the funds. However, no coherent pattern could be discerned.

Table 10

Errors in NSERC data

Projects identified as not AIM	30	16% of total projects identified by NSERC 88% of total misidentified
NSERC funding for these 30 projects (000)	1,779	
Number of these 30 projects classed by NSERC as peripheral	18	43% of projects identified as peripheral 51% of peripheral projects identified in responses received
NSERC funding for these 18 projects (000)	1,348	57% of total peripheral funding 67% of funding of peripheral responses 12% of total NSERC funding in sample

Changes in Funding

The CRS questionnaire also solicited information regarding changes in materials-related funding between 1987 and 1989. Of the 87 responses received, 59 (70 percent of responses, and 52 percent of the questionnaires sent out) provided this information. Based on these returns, the average increase in materials-related research funding from all sources between 1987 and 1989 was estimated to be 31.5 percent. Wide variations were reported, the values ranging from -100 percent (funding discontinued) to +400 percent. Large increases could frequently be attributed to the initiation of programs like the Ontario Centres of Excellence and the federal Networks of Centres of Excellence programs.

The data provided reflect a net increase of \$4,400,000 for this sub-set of the sample. Of the 59 responses, 6 indicated an increase of in excess of 100 percent; 34 reported increases between 0 and 100 percent; 10 indicated no change; and 9 reported a net decrease. The total increase, as derived from 1987 grants data and the percentage changes reported, was calculated to be \$5 million, which was offset somewhat by a decrease totalling \$600 thousand.

The small size of the dataset and the wide variations in it make suspect any generalizations based upon it.

Interviews

Visits were made by the author to the campuses included in the CRS "Research Letter" sample where the number of respondents and their availability for interviews made this worthwhile. The institutions visited and the number of faculty interviewed at each is outlined in Table 11. Unfortunately, most of the researchers selected by CRS for the sample survey at Dalhousie, Concordia and Guelph either failed to reply or replied that they did not consider their research to be materials-related. This is not to be construed as suggesting that most of the individuals identified in the composite list at these institutions are improperly identified. Rather, only the individuals who were selected for the sample can be described in this manner.

It was not possible to visit all researchers in the CRS research sample, due to time constraints and scheduling problems. In general, the academic connections and experience of the author were beneficial in arranging these interviews. There appeared to be considerably more willingness on the

Table 11

University interviews

University	Department or Faculty	Number of AIM Researchers	Average Grant (\$000)
Carleton University	Engineering	3	40
	Physics	1	8
Queen's University	Physics	3	121
	Chemistry	3	119
	Metallurgy	1	70
University of Toronto	Aerospace Institute	2	400
	Civil Engineering	1	88
McMaster University	Chemical Engineering	1	106
	Physics	1	203
	Materials Science & Engineering	5	256
University of Saskatchewan*	Electrical Engineering	2	120
	Chemical Engineering	1	38
University of Calgary	Electrical Engineering	1	66
University of Alberta	Electrical Engineering	1	127
	Chemical Engineering	1	110
University of British Columbia	Electrical Engineering	2	285
	Civil Engineering	1	30
	Metals & Materials Engineering	2	410
	Physics	1	328
Simon Fraser University	Physics	5	299
University of Victoria	Chemistry	2	30
McGill University	Chemical Engineering	1	163
	Metals & Materials Engineering	2	326

* Visit to the Saskatchewan Research Council also included.

part of faculty to spend time with a fellow academic who was conversant with their problems than might have been the case with others.

The purpose of the interview process was to supplement and clarify information contained in the NSERC/MOSST composite list and received in response to the CRS Research and Student letters, and to solicit qualitative information and opinions on a number of topics related to materials research. Such opinions are obtained with much greater ease

in a personal discussion than by means of a letter. The questions used to initiate the discussions centred on the following points:

- What was the area of training of the person being interviewed? Was it materials-related and/or related to the discipline currently being practised?

- How many graduate students were under the supervision of the person being interviewed and how many of these were involved in materials research?
- What are the perceived employment prospects, both industrial and academic, for new graduates in materials-related fields?
- What are the opportunities for joint research projects with industry and, where these have been established, how were they initiated?
- How can the "technology transfer" of research results to the undergraduate curricula of related departments be characterized?
- What are the research journals in each area where the most important results are being published?
- How accurate were the NSERC/MOSST assignments of the research of colleagues as being or not being involved in AIM research? Lists of researchers who had been missed or misidentified were compiled.

As can be seen from Table 11, the funding levels reported in the interviews confirmed that these were active researchers and were viewed as strong contributors to AIM research activity. Each interview required a minimum of twenty minutes and several lasted more than an hour. Discussion frequently ranged over a wide variety of related topics. Some aspects of the results of the interview process can be summarized in tabular form, but many of the more important results cannot. Among the topics which formed the main body of a number of protracted discussions were:

- Why are these surveys necessary and/or what are they good for?
- How can they be done more accurately?

In the following pages, a synthesis of a number of the points raised most frequently is presented, along with some criticisms and suggestions. The opinions

are necessarily a result of the author's personal filtering of the views offered by the interviewees.

Human Resource Data

To attempt to present a "snapshot" of the current situation regarding university researchers in AIM, an analysis of the age distribution and background of all those identified in the NSERC/MOSST composite list was attempted. From a variety of sources⁶, the year of birth and country of origin of as many individuals as possible from this list was constructed. The following assumptions were made, where the actual data were not available directly: the country in which an individual obtained his/her first degree was taken as the country of origin (the countries of origin were aggregated in the categories Canadian, U.K., U.S. and "Other"); the age at first degree was taken as 22 and the age at the PhD degree was taken as 27 years.

This type of information was not readily available for faculty in many francophone universities and therefore this group is markedly underrepresented in this aspect of the CRS analysis. The success rate of this line of enquiry is shown in Table 12, which indicates the numbers reporting in each category.

Table 12

Statistics on faculty identification

	Science	Engineering	Total
Age	172	158	333
Origin	202	214	422
Both	171	158	332 (58%)

⁶ "Directory of Graduate Research", American Chemical Society, Washington, D.C. 1990; *American Men and Women of Science*; Canadian Association of Physicists, Members Directory; Association of Professional Engineers of Ontario, Membership Directory; other directories of provincial engineering associations.

4. Analysis and Discussion

Analysis and discussion of the information assembled in the course of this study will look at the following areas:

- differences between science and engineering;
- definitions;
- opportunities for, and development of, joint projects;
- granting council/university policies;
- manpower (present and future) - supply and demand;
- curricula;
- surveys;
- miscellaneous.

In the material which follows, major points of emphasis and conclusions reached by the author are highlighted in italic type.

The Differences between Science and Engineering Disciplines

Faculty members of science and engineering departments have different problems, outlooks, opportunities and opinions which affect their participation in materials research.

Before discussing the results of the letters and interviews, it must be noted that two related but quite different constituencies were under scrutiny. Although basic investigation and development of a material with desirable properties may take place in any one of a large number of academic disciplines, the utilization of that material (i.e. the "industrial" part of AIM) is almost solely the province of engineers. It is abundantly clear from the responses to the letters and interviews that the types of problems and opportunities encountered by individuals in science (usually chemistry and physics) departments differ markedly in many respects from those encountered by individuals in engineering

(applied science) departments. This leads to a wide variation in attitudes and responses.

In general, the science faculty researchers study material at the molecular level, whereas much of the applied research is conducted at the macromolecular level. As was pointed out in the National Academy of Sciences study⁷, in science departments the relevance of research at a molecular level to "Advanced Industrial Materials" is frequently obscure even to those people directly involved, simply because they are further behind on the "time line" of materials development. As a result, a higher percentage of projects from areas of engineering and applied science may have been identified in the NSERC/MOSST composite list than is the case for projects from science departments. This is only one aspect of the "definition problem" which will be addressed more fully in the next section. The differences between science and engineering are also manifested in such diverse areas as the availability of industrial contacts, industrial funding, faculty training and background, and graduate student goals, to name only a few.

Definitions

Scientists are uncomfortable with generalized statements, but specific categories and definitions for materials research have proven elusive.

The terms "Industrial" and "Advanced" cause definitional problems for university researchers.

⁷ Materials Science and Engineering for the 1990s.

What is an "Advanced Industrial Material"?

A definition of exactly what constitutes an "Advanced Industrial Material" is crucial to any attempt to determine activity and funding in this area of research. It has also proven to be a most vexing and elusive problem. General statements have been proposed which appear to define the concepts. However, translation of these into definite areas with specific and clearly defined boundaries (a process which usually precedes surveys of this sort) has proven difficult.

Until recently, all attempts at such definition have been material-specific or material-type-specific. For example, the codes used by NSERC (Table 1) refer to specific materials (ceramics, metals, liquid crystals) or material-types (coatings, composites, etc.). It has been widely recognized⁸ that these definitions are unsatisfactory from several points of view.

1. The terms themselves are ill-defined. For example, technical dictionaries⁹ uses the term "composite" as part of the definition of a ceramic material, and yet the NSERC codes list the two separately.
2. The use of materials-specific definitions and codes by NSERC, particularly in their Strategic Grants in Industrial Materials and Processes program, has led to the support of a good selection of materials-related research. Few would question the inclusion of any of the selected projects in a list of materials research. However, the use of such definitions and codes will always cause difficulties when completely new materials are developed and for people at the "edges" of defined areas. For example, a number of references arose during the interviews to interest in electrorheological fluids and other "smart materials". These are clearly advanced materials, but even many existing examples cannot be classified satisfactorily using the NSERC codes; future developments will make this even more difficult. More mundane examples can be found in the areas of magnetic materials and corrosion studies, which cannot

⁸ "The Advanced Industrial Materials 1988 Canadian Sourcebook."

⁹ *Encyclopedia of Composite Materials and Components*, M. Grayson (ed.), Wiley, 1983; and *Encyclopedia of Materials Science and Engineering*, M.B. Bever (ed.), Pergamon, 1986.

easily be classified using the current codes. Correction of deficiencies in this system of classification has usually taken the form of adding new categories or dividing existing ones into more specific, rather than less specific, areas. The 1989 revision of the NSERC areas of application codes is a good example. The original areas have been expanded to 484 "definitions" in an attempt to give better coverage.

3. The difference between an industrial material and a commodity is not appreciated by many, and the terms "advanced" and "industrial" imply connotations which frequently are seen by university researchers to be contradictory. Can a material which is "industrial" (which implies being in large-volume production) be advanced, since by the time it has reached production, further research may have rendered it commonplace? Alternatively, can a material which is truly advanced also be in active industrial production and use? As one example of this paradox, NSERC did not consider concrete to be an advanced industrial material; nevertheless, several excellent research programs into advanced types, properties and uses of concrete are extant in Canadian universities, and the area has been recognized as one of the Networks of Centres of Excellence.¹⁰
4. Materials-specific definitions appear to be somewhat more efficacious when used in applied science. In many cases, even researchers directly involved in science research cannot easily perceive the relation of their work to the development of new materials, and rarely think of their work in this way, particularly when the adjective "industrial" is used.
5. Although many of the university researchers doing solid state chemistry or condensed matter physics do not view their work as relating to AIM, most experts in materials research consider these fields to be crucial to materials development.
6. Of all the codes used in the NSERC study, that referring to robotics led to the most spurious inclusion in the NSERC list of AIM projects. Prevailing opinion is that robotics research is rarely materials-related.

¹⁰ Networks of Centres of Excellence, 1989.

As will be seen in subsequent sections, a primary recommendation of this report will be that the adjectives "Advanced" and "Industrial" be avoided and that attention be focused on the whole "materials" area. For this reason, the terms "Advanced Industrial Materials" and "materials" should be taken as being synonymous in the rest of this report.

The National Academy of Sciences Study

The National Academy of Sciences (NAS) in the United States recently completed a large study of materials research.¹¹ Although their work focused only on the United States, many of the conclusions reached are worthy of consideration in a Canadian context, and some of the more important are noted below.

The NAS has largely abandoned the *materials-specific* definitions in favour of a definition which cuts across all materials classes. Classification of materials in terms of *functional roles* has the advantage of making explicit the link between fundamental research and its applications. This approach stems from a realization that the properties or phenomena which a material exhibits are of central concern, and that these are ultimately related to its composition and structure (i.e. which atoms are present and how they are arranged). For example, electronic materials can be semiconductors, polymers, ceramics, metals, etc. In developing a new material for a given application, the most important criteria are that it must perform the given task in an economically and socially acceptable manner. During the development of such a material, it is difficult to anticipate where seeking knowledge ends and applying it begins, and thus the distinction between science and engineering, which is reinforced by the use of materials-specific codes, is de-emphasized.

The following definitions were developed by NAS:

1. structure and composition
 - controls properties and phenomena and is a result of #2
2. synthesis and processing
 - controls #1

3. properties
 - driving force for development
4. performance
 - driving force for development

Categories 2, 3 and 4 are of primary industrial interest, whereas category 1 is more the province of basic research.

Two themes cut across all elements of materials science and engineering and are central to its success:

- the importance of instrumentation in all the above areas;
- the increasing importance of analysis and modelling. The general area of molecular design and other computational aspects of materials research is growing rapidly.

Determination of the structure and composition of materials (i.e. their analysis) is crucial to understanding their properties. Increasingly sophisticated and costly analytical instrumentation has increased the ability to perform such analyses and also increased the rate at which new materials can be developed. Such instrumentation tends to be very sophisticated and very expensive, and is often applicable to several material types.

The high cost of sophisticated instrumentation demands efficient use.

As the understanding of the relationships between properties of materials and their composition deepens, numerical modelling is being used increasingly as a substitute for much more expensive experimentation, but such work frequently demands access to state-of-the-art supercomputers.

Another view and approach to the definitional problem are contained in a recent article entitled "Materials for the Next Millenium".¹² Designers of future questionnaires should consult this article.

¹¹ *Materials Science and Engineering for the 1990s.*

¹² E.B. Hondros and E. Bullock, *Angewandte Chemie* (Int. Ed. Engl.) 28, 1088 (1989).

Joint Projects with Industry

During the interview process, inquiries were made regarding the existence and frequency of joint research projects with industrial partners. During these discussions, a remarkable unanimity of opinion was encountered regarding a number of points.

General Comments

Joint projects with industry must benefit both parties.

Of prime importance to the materials research efforts in Canadian universities are strong industry-university ties, particularly in the area of joint research programs. The benefits to all from successful collaboration are well documented. During the interviews conducted in this study, an attempt was made to ascertain how some of the more successful joint research efforts had been initiated.

The importance of an arrangement whereby both parties benefit was emphasized. Many university researchers feel that industry often views its support of university research projects as a cheap way to solve a short-term problem, and that no advantage accrues to the university. This is in addition to simple consulting arrangements between industry and faculty members, which may lead to financial gain for the individual but no real university research.

It must be recognized that a primary role of universities is to train a cadre of highly qualified manpower, at both the undergraduate and graduate levels. Much of the research is carried out by students, and used for the training of students. Insofar as this is true, research cannot be separated from the teaching function. Another primary role is to extend the frontiers of knowledge. Research which does not qualify either for thesis work or for publication because of confidentiality requirements or for other reasons can perhaps be viewed as being done at the expense of the university's "major products".

All university researchers interviewed expressed strong interest in research collaboration with industry. However, their contacts with their counterparts in industry and therefore opportunities for joint research projects appear to be concentrated in, although not confined to, the more applied areas.

This is perhaps due in part to the use of traditional (materials-specific) methods of describing materials which frequently are related to applied projects. Thus most of the industrial funding which supplements the traditional NSERC funding base goes to engineering departments.

There is a noticeable feeling of isolation among researchers at universities in western Canada. This was expressed most frequently in Saskatchewan and British Columbia, where the feeling was that the opportunities for industrial contacts and joint projects were better in central Canada. Interestingly, no one expressed this notion in Alberta.

Time Frame and Proprietary Information

The time frame (short for industry, longer for graduate student projects) can be a problem for collaborative research involving graduate students, as can concerns for proprietary information.

A principal requirement for obtaining an advanced (MSc or PhD) degree is the publication of an original research project. Such programs usually last from one to four years. Industry usually wants its results more quickly. Therefore, in order to have an industry-related project serve as a suitable topic for graduate student research, it must be publishable with minimal delay and it must be of sufficient scope to allow the student to obtain the number and quality of results required for the thesis. The funding of such a project is the "benefit to the university" referred to in the previous section. However, it cannot work where there is a requirement to keep proprietary information secret. The scope of a thesis research project is frequently a problem, for small- to medium-sized industry whose time frame for results is measured in terms of months instead of years.

Research in universities that is not carried on by graduate students usually involves research associates and/or postdoctoral fellows. The confidentiality problem may limit publishing opportunities in these instances. Furthermore, projects of limited duration and scope may present major problems in terms of finding personnel to carry out the work, since without assured long-term funding, it is difficult to obtain competent assistants.

The "benefit to industry" is primarily the opportunity for access to a knowledge base and the specialized skills and equipment required for the work, without incurring the high capital costs which would put the project beyond the means of many interested companies. The recruitment aspect arising out of such projects may be a second "benefit".

Personal Contacts

Many successful collaborative projects arise from personal contact between university researchers and individuals in industry.

Fully three-quarters of the people interviewed who had had experience with joint projects with industry indicated that personal contacts played a key role in initiation of the project. Typical scenarios involved contact with ex-students or ex-colleagues in industry, friends from previous school days (graduate and undergraduate), people met at conferences, etc. In surprisingly few cases had industry approached a faculty member about a joint research project because of his(her) perceived expertise in a particular area.

It is common to encounter researchers working in a materials-related areas in university engineering departments whose background and experience were obtained in a completely different field. In many instances, such individuals have "migrated" into the materials area during a sojourn in an industrial setting, and they bring to the university the industrial contacts necessary for developing joint projects. The cross-linking of different disciplines and the contacts with, and understanding of, industrial concerns they bring to their departments is an obvious source of strength. This has been well recognized by many university departments, and several mechanisms have been devised to take advantage of it. Principal among these is the creation of an institute, specializing in one or more aspects of materials science.

Institutes and Departments of Materials Science - "Centres of Activity"

When properly constituted and run, institutes represent efficient use of funds and promote interdisciplinary research.

Unfortunately, not all institutes run this way.

Certain universities have units which are dedicated to one or more areas of materials research. Typically, a separate department (usually called a Department of Materials Science) evolves from a department of metallurgy. In many cases, the specialities of the professors as well as the teaching and research focus of the department reflect this heritage, and heavy emphasis remains on metals and metallurgy. At the same time, significant efforts are being made to broaden this base by adding faculty members who have other areas of materials expertise, such as ceramics, composites, and polymers. Examples (but not a comprehensive list) of universities where this process appears to be proceeding well are McMaster, McGill and the University of British Columbia. The latter example is one which demonstrates the inaccuracies in the NSERC and MOSST studies. This department lists 21 faculty members, all of whom claim to be involved in materials research. However, only 9 were identified in the NSERC/MOSST composite list.

The diversification of metallurgy departments into broader areas of materials research described above has put severe strain on the continuing ability of the departments to carry on their traditional research activities.

In other cases, departments at the same or different universities link up to provide expertise in a single or broad base of materials areas. Such linking is frequently designated as an "Institute". It can be distinguished from the (Networks of) Centres of Excellence by the fact that all parts are located in close proximity to one another. An example of a single-focus institute is the polymer group at McGill and École Polytechnique, which has over 30 faculty and over 70 graduate students currently registered. The concentration of expertise in a single area is highly attractive to industry.

Another approach is to draw faculty from several different departments, principally from the

same university, who have interest and expertise in different areas, all of which relate to materials research. The most obvious examples of this type of arrangement are the Institute for Building Studies at Concordia University and the Institute for Materials Research at McMaster University. The latter has over 50 faculty drawn from 7 departments supervising over 70 students and 35 postdoctoral fellows. The expertise spans 7 of the 10 NSERC-defined areas of AIM. Funding for the programs (in addition to the NSERC operating grants of the individual researchers involved) comes primarily from the Ontario Centres of Excellence Program (Ontario Centre for Materials Research). Several other universities (e.g. Queen's, UBC) are apparently actively engaged in initiating interdisciplinary research in the materials area.

When properly administered and run, institutes offer large savings by virtue of the sharing of instrumentation purchases and maintenance costs. In addition, the industrial interactions can be dramatically enhanced in a well-organized institute by shared contacts and seminars, for example. They are the closest approach to the Materials Research Laboratories established in the United States. However, it seems certain that, without changes in granting council policies (see below), such institutes will have difficulty reaching their potential.

For surveys of the type conducted for this study, institutes can offer both significant advantages and disadvantages. Those involved in directing such units have an appreciation of, a deep interest in, and a high level of familiarity with all areas of materials research. As a result, they are highly useful resource persons. The lengthy discussions held with a number of these individuals during the interview process were instrumental in shaping many of the conclusions contained in this report. On the other hand, when student numbers are considered, it is extremely difficult to avoid double-counting since many students are officially registered in departments, but carry out their research in institutes.

In other cases, prevailing opinion is that institutes are being created solely to attract funding and no real interactions result. Faculty members may be part of an institute only by virtue of having their name on a list. Impressions received from several individuals can be best summarized by quoting one comment, "How can effective interdisciplinary research be carried out when the members of the group are all located in their own departments, with

their own students and equipment, and the only time they see each other is at a monthly meeting?"

Granting Council Policies

Perceptions of granting council policies can be a deterrent to collaborative research.

Granting council policies materially affect the attitudes of researchers towards cooperative research, especially at the local level, with other faculty members. It is the opinion of the majority of researchers interviewed who are not involved in high-powered programs like the (Networks of) Centres of Excellence that the operating principles of the most important funding agency, NSERC, discourage cooperative research. It is well known that publication records are an important part of the granting process, but the "sharing" of publication credit for any paper is widely viewed as having a strong negative effect on NSERC decisions. This perception may be incorrect, but its wide acceptance in the university scientific community is a real deterrent to cooperative research efforts.

In addition, in the operating grants program, no single NSERC granting committee can effectively examine a project which spans more than one discipline. The practice is to ask all concerned committees to examine such proposals. The perception of researchers is that each of these committees gives low priority to interdisciplinary projects because the project's main focus is seen to come under the purview of another committee. The high failure rate for such proposals is attributed to this fact. The strategic grants program does not suffer from this problem and is seen as an ideal model.

Without global, locally controlled research support, the potential of institutes for growth and excellence and their contribution to science and society will be severely restricted.

Another direct impact of the policies of NSERC derives from the fact that its program of operating grants program (which are the lifeline of the academic researcher) is directed towards people and individual projects. Although infrastructure and other types of grants to support the administration of the operation of centres of activity are available, locally controlled global budgets for the direct

support of research are not. Without this kind of support, the potential of such units for growth and excellence and their contribution to science and society will be severely restricted. It is the consensus that adding a mission statement to NSERC to allow such global research grants and additional resources to fund them would, in large part, rectify the problem.

The administrative operations of NSERC are seen to be excellent.

NSERC's administrative operations and peer review system effectively avoid political pressures and are considered to be excellent.

Human Resources

Faculty

There is a significant change in the age profile of Canadian engineering academics in general. The trend for materials-related faculty is similar.

The training of MSc and PhD candidates in materials science, as in any other area, is crucially dependent on the number and expertise of university faculty members. A recent document¹³ has summarized the trends in engineering faculties in general. Among the findings presented, perhaps the most significant concerns age distribution. Those data (Figure 8) shows that, in 1986, 41 percent of all engineering faculty were 50 years of age or older and only 24 percent were under 40. The numbers for 1976 were 25 percent and 36 percent respectively. This comparison highlights the deterioration in the age profile of this key group of academics.

The categories used in the ISTC analysis did not specifically identify materials-related faculty. An attempt to remedy this was made by CRS, and the results are shown in Figure 8, along with the data for engineering faculty as a whole. This comparison is not entirely valid, since many of the identified materials-related faculty are in science rather than engineering departments. Nevertheless, the consequences of the trends could be alarming for materials teaching and research. The situation can be summarized as follows.

¹³ "Statistics on Engineering in Canada", ISTC, 1989.

1. As can be seen from Figure 8, the overall age distribution for identified materials-related faculty members is significantly older (56 percent over 50, 11 percent under 40) than even the general engineering case.
2. The age profile peaks in the 51-55 year range (Figure 9).
3. Canadian faculty members represent about one half of the total (Figure 10); i.e. almost half of the teachers and researchers received their training elsewhere.
4. As shown in Figure 11, the proportion of Canadian faculty, after falling significantly in the older age groups, has rebounded in the group of younger faculty. However, the total number in the youngest group has suffered a severe decline. This appears to be a general trend in science and engineering departments in general. Due to both a lack of qualified people and to financial restrictions, severe difficulty in hiring new faculty is routinely encountered. This may reflect increased industrial opportunities for these people, who will be responsible for Canada's future in materials research. Some new initiatives, such as the use of bridging appointments, are being used by some universities to alleviate this problem.

In the absence of remedial measures, in ten years a decrease in the number of faculty involved in materials research will occur. The result may be a decrease in materials funding and in student opportunities in this area.

Analyzing the data from another perspective, Figure 12 shows that 50 percent of Canadian-trained and 54 percent of foreign-trained materials-related faculty are over 50 years of age, whereas 16 percent of Canadians and 8 percent of foreign faculty are under 40. In other words, fewer new young faculty members are being attracted from abroad to Canadian teaching and research positions. If the trend continues, in ten years a sudden decrease in the number of faculty involved in materials research will occur. This will affect both the teaching and research aspects of university materials-related de-

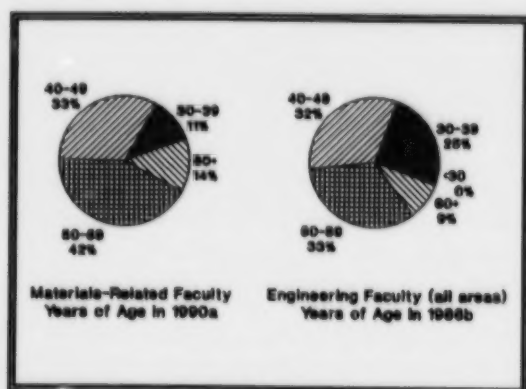


Figure 8. Overall age distribution

^a based on 333 individuals (58%) identified

^b Source: Statscan

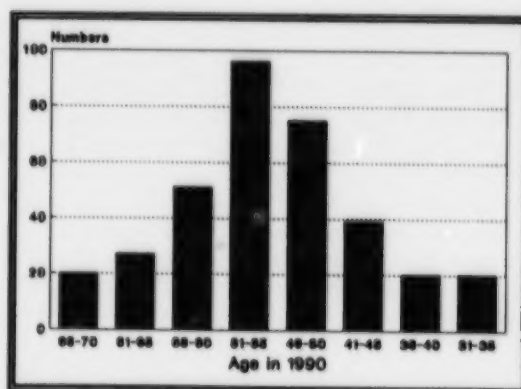


Figure 9. Overall age distribution

(without regard to nationality)

based on 333 (58%) identified

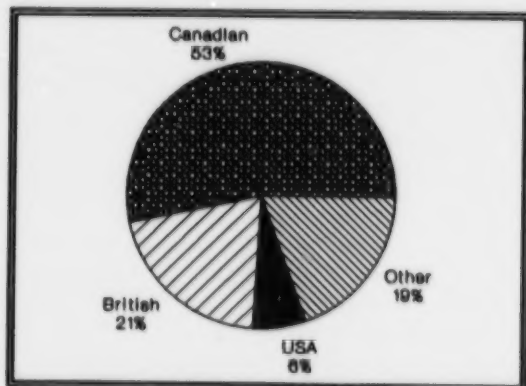


Figure 10. AIM faculty by nationality

based on 422 (74%) total identified

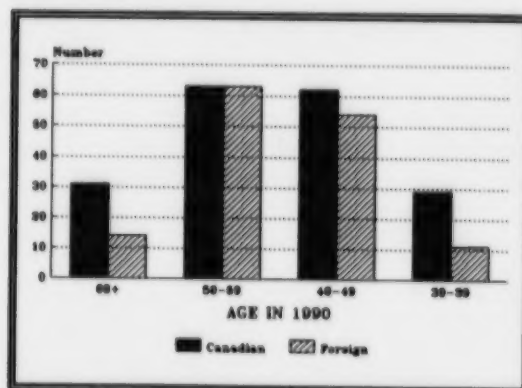


Figure 11. Age distribution vs. nationality

based on 332 (58%) identified

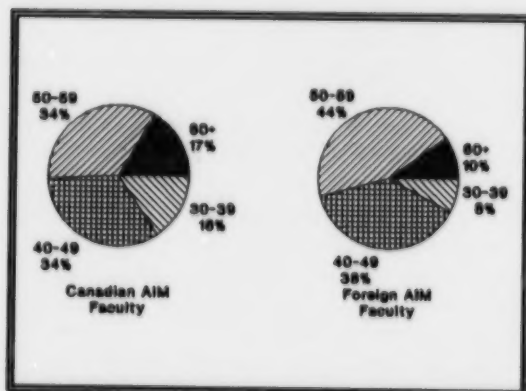


Figure 12. Age distribution vs. nationality age in 1990

based on 322 (58%) identified

partments. Many of the retiring faculty are heavily funded. Traditionally, younger researchers tend to receive smaller NSERC grants and less other research support than their better-established colleagues. Therefore, unless steps are taken to change this distribution, the result could be a decrease in the amount and quality of university materials research, and hence a decrease in research funding. Because much of the student financial aid is derived from these funds, a decrease in funding would translate directly into a decrease in student opportunities in this area.

The industrial experience of new engineering faculty members will help in the establishment of future joint research projects.

In summary, it seems clear that a significant new infusion of foreign-trained researchers and academics will be required just to maintain the current level of research activity. However, the availability of such highly trained people is called into question by the rapidly escalating global demand for their services.

It is common to encounter a person working in a particular materials-related area in an engineering department whose background and experience have been in a completely different field. Furthermore, it has been noted that fully 20 percent of newly employed engineering professors came from industry.¹⁴ This will have a significant effect on the age profile of engineering professors since it will delay their entry into the academic area. However, as noted previously, this industrial experience augurs well for increased cooperation and contacts between university and industrial research groups in the future. It also suggests possible sources of relief for the forecast shortages of AIM teaching and research personnel in engineering departments. However, such movement from industry to university is much less common in science departments.

The larger percentage of materials-related graduate students who are taking PhD programs suggests that more interest in academic jobs may be evolving, since it is this group which traditionally occupies these positions. This may also provide some expansion in the number of future researchers.

¹⁴ *Ibid.*

Students

Supply

In 1988-89, there were just over 3500 students enrolled in engineering MSc programs and 2000 in PhD programs in Canadian universities.¹⁵ Electrical, mechanical and civil engineering, all disciplines which have a significant materials component, account for the majority of these students. However, it is not possible to state how many of these students are directly involved in materials research. A source of concern for many is the rapidly decreasing number of Canadian students pursuing graduate studies, particularly in engineering. In 1988, 20 percent and 40 percent respectively of the engineering MSc and PhD degrees awarded were to foreign students and in 1988-89 more than 50 percent of all students pursuing engineering PhD degrees were foreign.

It is impossible to speculate on the implications of this situation for future human resources without more information on the career plans of these students: do they, whether Canadian or from abroad, intend to practice their profession in Canada? The distribution of materials-related graduate students, as indicated by the survey (Table 13) and subject to the caveat stated for the student data collected for this study, can be summarized as follows:

- A larger percentage (54 percent) of materials-related engineering students are in PhD degree programs than is true of the whole spectrum of applied science students. For materials-related science students, 65 percent are in PhD programs which is marginally lower than expected;
- A higher percentage (62 percent) of materials-related science students are Canadian than is the general case. In engineering, 39 percent of all materials graduate students are foreign;
- The majority (65 percent) of students in materials-related research are in engineering rather than science programs.

¹⁵ *Ibid.*

In both applied science and science areas, many students find their first permanent employment through the personal contacts of the research supervisor. Students are very aware of this and it affects their selection of supervisors and schools. Cooperative programs are also viewed by students as an excellent way of obtaining a suitable position.

The job market for students at all levels of training in applied science related to materials research was identified as a deterrent to pursuing an advanced degree, particularly a PhD.

The notable difference in the percentage of people continuing on to a PhD degree in the sciences and engineering (Table 13) can be attributed to this fact.

The shortage of qualified personnel and the vigorous competition for their services has led industry to offer very attractive terms of employment to the best students before they enter or complete graduate programs. This removes some of the most promising potential future university teachers and researchers.

Demand

Industrial opportunities for materials-trained students, especially for applied science students, are excellent.

In general, the employment prospects of graduates in applied science, as predicted during the interview process, seemed excellent. Phrases like "it's a seller's market", "industry can't find enough" and "they are hiring them before they complete their degrees" were commonplace. Some individuals were less optimistic, citing the delicate relationship between materials-related industry and the economy in general. Geographic differences in viewpoint emerged, with negative views heard more frequently from centres in western Canada.

Members of science (chemistry and physics) departments were somewhat more cautious in their assessments. With some notable exceptions, the Canadian industry associated with these disciplines is not oriented toward materials-related technology. Perhaps the major exceptions are the pharmaceutical/biotechnology and space industries but,

under the present criteria, the former are not included in the "materials" area.

The requirement for a PhD degree, in order to obtain a faculty position, combined with the perceived low pay and aging facilities in academia and the excellent remuneration in industry for BSc and MSc materials graduates, ensures that few who are not already committed to an academic future will pursue the PhD degree. The implications of the statistics on student enrollment do not augur well for the future of university applied science faculties.

Two truisms were repeated frequently:

- *Good students always get jobs.* However, the true test of a job market is not whether the truly outstanding students are able to find jobs, but rather how many offers they receive, and whether the "ordinary" student also has significant job opportunities.
- *The market for talent in materials research is global.* This is true in all areas of science and engineering.

Canada is competing for the best talent in this market and is also supplying the market with highly qualified people. Canadian industry and universities cannot expect, nor should they, to be the preferred choice of graduates of Canadian universities, or to attract off-shore talent, without competing with and matching other countries in terms of facilities and salaries.

The science and engineering disciplines most prominent in the materials area (e.g. chemistry, physics, metallurgy, chemical and mechanical engineering) are also relatively mature disciplines, and many faculty retirements are anticipated in the next ten years in these departments. Even at the present time, almost every chemistry department is either looking or preparing to look for new faculty (not necessarily in materials-related areas), and finding the search difficult.

The interdisciplinary aspects of AIM research are relatively new. Opinions gathered in the interviews regarding the strength of demand for students indicate that the training offered in departments or institutes of materials science which are truly interdisciplinary appear to produce students who are in the greatest demand by materials-intensive industries or university departments.

During the interviews, several faculty members commented on the danger of a very few industries dominating the job market for students with particular expertise. The example most often cited was the large percentage of materials-trained electrical engineers who are being employed by a single firm, Bell Northern Research. Broadening the base of the industrial research effort in materials should be a top-priority item, since basing the demand for a certain type of student on a single firm or a single market has obvious potential for future problems.

Curricula

The development of new courses of study which reflect the current state of the art in materials science must be a priority.

As part of the process of gathering data on student training, opinions were sought regarding the incorporation of materials-related topics into the undergraduate curricula. The question asked was, "How much would a newly graduated student know about different types of materials and their properties?" Some universities, notably those which have a true and effective materials science department or institute, indicated that the knowledge level could be classed as "moderate" and that new course development was under active consideration.

Most opinions were that coverage of this aspect of "technology transfer" in undergraduate curricula is abysmally inadequate. Students in civil engineering learn about concrete and steel, but very little about other metals or polymers, while the reverse is true for students in chemical engineering or metallurgy. Where materials courses are included in the curriculum, the emphasis depends on the interests of the individual instructor. Perhaps the situation can be best summarized by the following statement from one faculty member: "Metallurgists discuss concrete or polymers as degenerate metals, whereas civil engineers think metals are degenerate concrete."

The development of new courses of study which reflect the current state of the art in materials science must be a priority. This requirement was also noted in the National Academy of Sciences (NAS) study.

Surveys

University faculty are becoming increasingly irritated about the number of questionnaires they are asked to complete which, in their view, require too much of their time with no apparent benefit.

As was noted in the introduction, many other surveys in the area of materials science have been and are being carried out by government, industry and other organizations. University researchers and administrators are becoming increasingly irritated about this activity which, in their view, is requiring too much of their time with no apparent benefit. Institutes appear to be an exception to this position, possibly because they have secretarial assistance to deal with such requests, or possibly because they owe their existence to promoting interest in their field. However, in an institute, the professional researchers' input into the responses may be minimal, and the quality of the information may be uncertain. Directors of such departments and institutes admit that every effort is made to promote the whole area of materials research, and to raise their profile in it in terms of breadth and depth of expertise and amount of funding.

Faculty in the materials area are also being inundated with requests for information not directly related to materials science (e.g. the recent NSERC equipment survey). The level of resistance to answering surveys in general is rising rapidly, and several of those interviewed said they had received the MOSST questionnaire, but could not see any valid reason to complete it. All of these factors have a major effect on the quality of information obtained by questionnaire.

If future data collections are to be more successful, cognizance must be taken of the above points and researchers must be persuaded of the importance of their participation.

Perhaps the most important question to be answered is how the data-gathering process can be better accomplished. It must be noted that such a process involves two distinct steps: identification of people involved followed by the gathering of information from these individuals. Several strong opinions were expressed on how this should be done.

1. *Lists should be based on people.* The composite list in the appendix to this report, supplemented by the additions and deletions list could form a realistic start to this process.
2. *The properties-specific classifications used by the NAS should be used as the primary filter,* but the materials-specific codes must be retained, particularly for those people in applied science. The term "advanced industrial materials" (AIM), with all its negative or confusing connotations, should be replaced. Reference to the "next generation" of materials might be useful.
3. A very few key people in each area could examine the preliminary list to suggest additions, but everyone will have to accept that *no list will ever be 100 percent correct.*
4. Governments (both provincial and federal) and their granting councils should aim to *standardize the format in which data are requested.* This would save enormous amounts of time and effort and lower the resistance to responding to requests for data.
5. The area described by NSERC as "Robotics" *should be eliminated from the AIM categories.* In its place, a category encompassing numerical analysis and modelling should be offered.
6. Once the list of people has been established, *much less reliance should be placed on questionnaires and much more on interview situations.* Data obtained by talking to people are much more reliable and useful than those obtained using questionnaires. Although the interview process is more expensive, the results are clearly worth the effort and expense.

Miscellaneous

Publishing Loci

As noted, inquiries were made during the interview process regarding where the most important results in materials research were appearing. As in all other areas of science and engineering, there has been a rapid proliferation of new journals, mainly commercial, devoted to materials science. The

intent of this question was to determine if future bibliographic searches, centred on selected journals, could be used to identify Canadian participation in particular areas with any degree of certainty. It rapidly became clear that no useful conclusion could be reached. Faculty working in apparently identical areas gave widely divergent views on what are the key journals, suggesting that such searches will not be very useful. The proliferation of journals in all fields, along with the relative youth of materials science and growing constraints on library budgets, raises the concern that libraries may not be able to stock the key journals, particularly in view of this lack of consensus.

Faculty Additions and Deletions

Perhaps one of the most telling results of the interview process lay in the assessment, by those being interviewed, of the validity of inclusion and/or exclusion of some of the colleagues on the NSERC/MOSST composite list. Individuals, speaking in confidence, frequently expressed doubts whether the research of others on the list was truly materials-related. Conversely, individuals who did not consider themselves to be in the materials area were identified by others as being key players in the research area. This situation occurred with colleagues in the same department and university, and with others at different institutions. This underlines the previously discussed differing perceptions of what constitutes materials research and the difficulty in the definition of the term "materials".

Finally, when names of "people who had been left off the list" were solicited, both in the interview process and in the letter to each department, many were submitted. These are collected in Appendix C. Although the methods used to collect these names suggest that the list should be reasonably comprehensive and accurate, no effort has been made to verify this point.

5. Conclusions and Recommendations

Conclusions

AIM Research Organization

Institutes, when properly run, can provide efficient use of funds and concentrated sources of expertise. The high cost of instrumentation and equipment demands efficient use, and institutes can be a means to this end.

Opportunities exist for collaborative work involving industry and university researchers, but both parties must benefit. The initiation of such projects occurs in many ways, but primarily by personal contact between the faculty member and someone in industry. The long time frame required for academic research and industry's need to protect proprietary information are deterrents to joint industry-university projects. On the positive side, the industrial experience possessed by many new faculty members should facilitate joint ventures.

There are significant differences in the perceptions, attitudes, funding opportunities, etc., between engineering and science departments.

NSERC policies on shared credit for research publications are perceived by researchers as deterring collaborative research.

Human Resources in Advanced Industrial Materials

Opportunity for employment in the materials area is excellent. This may aggravate the potential shortage of future faculty members in the AIM area in Canadian universities.

Although the *percentage* of faculty members who received their first degree in Canada rather than abroad is increasing in the younger age group, the total *number* of such faculty in the younger age group is smaller than expected. The average age of all materials-related faculty is higher than the overall average of engineering faculty.

This apparent discontinuity in the age distribution of materials-related faculty will cause problems in the staffing of university faculty positions in the near future, as the older group reaches retirement. Unless special efforts are made to increase the number of faculty and university researchers entering the materials field, the present trend indicates that a drop in both funding and personnel will occur in the next decade.

In a few years' time, the amount of government funding to materials research may decrease, if the number of researchers decreases and at the same time their average age falls. This could translate directly into fewer graduate students and less support for graduate research.

Incorporation of AIM in the University Curriculum

In most universities, curricula are badly out of date in the materials area.

Definition of "Advanced Industrial Materials"

The difficulties enumerated regarding the definition of an "Advanced Industrial Material" are the source of most of the problems in constructing a valid database. Areas such as biomaterials, magnetics, and "smart materials" were missed by NSERC and are difficult to identify with the usual materials-specific classifications. The National Academy of Sciences has used properties-specific definitions to advantage.

The terms "advanced" and "industrial" appear to be impediments to data collection.

The NSERC List

NSERC classified 32 percent of the projects it identified as being "peripheral". From the sample survey, 50 percent of these were not really materials-related. Therefore, approximately 85 percent of the people and projects on the NSERC list agreed they were truly involved in materials research. However, many people funded by NSERC but not included in its list also consider their work to be materials-related. Many of these people are funded by other granting agencies, in addition to their NSERC support.

The MOSST List

Using the NSERC definitions, we found the individuals in the MOSST list are truly involved in materials research. However, the list is very incomplete.

Surveys

University people do not understand why so much of this type of data is being collected. They view such surveys as dictated by the whims of bureaucrats, and are reluctant to spend the time and effort to fill out questionnaires. The problem is exacerbated by the many different questionnaires from many different organizations being circulated at the present time.

Recommendations

- The policies of granting agencies should be examined to ensure that high-quality, collaborative, interdisciplinary research is considered at least equally with the more traditional single-discipline projects, and that this fact is effectively communicated to the research community.
- Effective ways of increasing the numbers of materials-related faculty and funding must be sought. Detailed consideration must be given to the supply of Canadian and foreign-trained

researchers, as well as the funding patterns and areas of expertise.

- Efforts must be made to upgrade the level of undergraduate materials education. The development of new courses of study which reflect the current state of knowledge and research in materials science must be a priority.
- The properties-specific classifications used by the National Academy of Sciences should be used as the *primary* filter to determine who is involved in materials research, but the materials-specific codes must also be retained, particularly for those people in applied science.
- The term "advanced industrial material" causes many problems and should be replaced by "material" alone, or perhaps prefaced by "the next generation". This should eliminate many conceptual problems.
- Future data gathering should be based on *people* rather than project titles or subject areas. The composite list in Appendix A, supplemented by similar lists from other granting councils (to ensure coverage of types of research and materials not funded by NSERC) and the additions and deletions lists (Appendix C) could form a realistic start to this process. A few key people active in research in each area could examine the preliminary list to suggest additions.
- Requests for information must request the "funded grant title".
- In universities where there is a department or institute concerned with materials, requests for data of this type should be directed to the administration. In other universities, a contact person (e.g. in the university research office) who has a responsibility for and interest in providing such data should be designated to ensure that information is gathered from appropriate people.

- Governments (both provincial and federal) and their granting councils should attempt to standardize the format in which data are requested. This would save time and effort, and lower the resistance to responding to requests for information.
- If surveys of this sort are viewed as useful, effort must be expended to inform and persuade university faculty of the importance of the type of data collected in this and other surveys to their own research operations and to future funding levels in the field. Its usefulness for industry/university contacts should be emphasized. In conducting such surveys, the use of questionnaires should be minimized and the use of personal contact (interviews) should be maximized.

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Appendix A

The Composite List

The annexed list was derived by CRS from the MOSST and NSERC studies. The entries are sorted first by university, second by department and third by name of researcher. Many unidentified duplicate entries may remain in the list, as either M or N, in spite of efforts to identify all duplicates as "B".

The Source Code is:

- | | | |
|---|---|--|
| M | = | MOSST (i.e. listed only in the original MOSST study) |
| N | = | NSERC (i.e. listed only in the original NSERC listing) |
| B | = | Both (i.e. listed by both MOSST and NSERC) |

University and Department	Name	Source
<i>Acadia University</i>		
Department of Physics	B. Latta	M
<i>Brandon University</i>		
Department of Physics	R.Y.Y. Dong	B
<i>Brock University</i>		
Department of Chemistry	J.S. Hartman	M
Department of Chemistry	J.M. Miller	N
Department of Chemistry	M.F. Richardson	M
Department of Physics	F.P. Koffyberg	N
Department of Physics	B. Mitrovic	N
Department of Physics	F.S. Razavi	N
<i>Carleton University</i>		
Department of Civil Engineering	G.A. Hartley	N
Department of Civil Engineering	A.P.S. Selvadurai	M
Department of Electrical Engineering	M.A. Copeland	N
Department of Electronics	A.R. Boothroyd	N
Department of Electronics	B.A. Syrett	N
Department of Electronics	N.G. Tarr	N
Department of Electronics	R.E. Thomas	N
Department of Physics	J. Armitage	M
Department of Systems & Computer Engineering	C.M. Woodside	N
Mechanical & Aeronautical Engineering	M.J. Bibby	N
Mechanical & Aeronautical Engineering	M.C. De Malherbe	N
School of Business	V. Kumar	N
<i>Collège Militaire Royal de Saint-Jean</i>		
Département de Physique	A. Filion	M
Département de Physique	M.M. Perlman	M
Groupe de recherche sur les diélectrics	A. Rambo	M
Groupe de recherche sur les diélectrics	S. Subramanian	M
Groupe de recherche sur les diélectrics	J. Zauhar	M
<i>Concordia University</i>		
Centre for Building Studies	D. Feldman	B
Department of Chemistry	J.A. Capobianco	N
Department of Chemistry	C.H. Langford	B
Department of Chemistry	M.F. Lawrence	B
Department of Electrical Engineering	N.J. Dimopoulos	N
Department of Electrical Engineering	S.M. Faruque	N
Department of Electrical Engineering	J.F. Hayes	N
Department of Electrical Engineering	B.A. Lombos	B
Department of Electrical Engineering	O. Schwelb	N
Department of Electrical Engineering	P.D. Ziogas	N
Department of Mechanical Engineering	P.H. Bird	B

University and Department	Name	Source
<i>Concordia University (cont'd)</i>		
Department of Mechanical Engineering	R.M.H. Cheng	N
Department of Mechanical Engineering	G. Denes	M
Department of Mechanical Engineering	P. Fazio	M
Department of Mechanical Engineering	S.V. Hoa	B
Department of Mechanical Engineering	R. Le van Mao	M
Department of Mechanical Engineering	S. Lequoc	N
Department of Mechanical Engineering	N.M.P. Low	M
Department of Mechanical Engineering	H.J. McQueen	B
Department of Mechanical Engineering	N. Serpone	M
Department of Mechanical Engineering	J.V. Svoboda	N
<i>Dalhousie University</i>		
Department of Chemistry	N. Burford	N
Department of Chemistry	J.C.T. Kwak	N
Department of Chemistry	P.D. Pacey	M
Department of Physics	R.A. Dunlap	B
Department of Physics	D.J.W. Geldart	N
Department of Physics	M.H. Jericho	M
Department of Physics	B.E. Paton	B
<i>École de technologie supérieure</i>		
Département d'Électricité	L.A. Dessaint	N
Département d'Électricité	E. Goodman	N
<i>École Polytechnique de Montréal</i>		
Département de chimie	P.G. Lafleur	N
Département de génie chimique	P.F. Bataille	B
Département de génie chimique	P.J. Carreau	B
Département de génie chimique	C. Chavarie	N
Département de génie chimique	M. Grmela	N
Département de génie chimique	T.M. Malik	N
Département de génie chimique	M. Meunier	B
Département de génie chimique	S. Sapieha	B
Département de génie chimique	H.P. Schreiber	B
Département de génie électrique	C. Akyl	N
Département de génie électrique	R.G. Bosisio	N
Département de génie électrique	P.J. Cohen	N
Département de génie électrique	R.M. DeSantis	N
Département de génie électrique	J.E. Houle	N
Département de génie mécanique	B. Fisa	M
Département de génie mécanique	R. Gauvin	B
Département de génie métallurgique	C.W. Bale	N
Département de génie métallurgique	J.I. Dickson	B
Département de génie métallurgique	J.-M. Dorlot	M
Département de génie métallurgique	G. L'Esperance	B
Département de génie métallurgique	A.D. Pelton	B
Département de génie métallurgique	M.A.J. Rigaud	B

University and Department	Name	Source
<i>École Polytechnique de Montréal (cont'd)</i>		
Département de génie métallurgique	Y. Verreman	M
Département de génie physique	J. Bures	N
Département de génie physique	J.F. Currie	B
Département de génie physique	S. Lacroix	N
Département de génie physique	J. Lapierre	B
Département de génie physique	R. Maciejko	B
Département de génie physique	E. Sacher	N
Département de génie physique	H. St-Onge	N
Département de génie physique	M.R. Wertheimer	B
Département de génie physique	A. Yelon	B
Département de métallurgie	L.R. Cutler	N
Département de physique	S.I. Najafi	N
Department of Mechanical Engineering	A. Bazergui	M
Department of Mechanical Engineering	T. Bui-Quoc	M
<i>INRS</i>		
Département de l'Énergie	L.H. Dao	N
Département de l'Énergie	J.P. Dodelet	N
Département de l'Énergie	H. Pepin	N
Département de l'Énergie	R.G. St-Jacques	N
<i>Lakehead University</i>		
Department of Chemistry	N.A. Weir	N
Department of Civil Engineering	S.A. Mirza	N
Department of Electrical Engineering	J.B. Kiszka	N
Department of Physics	M.H. Hawton	N
Department of Physics	W.J. Keeler	N
Faculty of Engineering	D.M. Barry	N
<i>Laurentian University</i>		
Department of Chemistry	Y.N. Sadana	N
<i>McGill University</i>		
Department of Chemical Engineering	J.M. Charrier	N
Department of Chemical Engineering	D.G. Cooper	N
Department of Chemical Engineering	J.M. Dealy	N
Department of Chemical Engineering	W.H. Gauvin	N
Department of Chemical Engineering	M.R. Kamal	N
Department of Chemistry	G.R. Brown	M
Department of Chemistry	I.S. Butler	N
Department of Chemistry	T.H. Chan	N
Department of Chemistry	A. Eisenberg	B
Department of Chemistry	D.F.R. Gilson	N
Department of Chemistry	D.G. Gray	B
Department of Chemistry	J.F. Harrod	B
Department of Chemistry	R.S.J. Manley	N

University and Department	Name	Source
<i>McGill University (cont'd)</i>		
Department of Chemistry	R.H. Marchessault	B
Department of Chemistry	L.E. St. Pierre	N
Department of Electrical Engineering	E.L. Adler	N
Department of Electrical Engineering	V.K. Agarwal	N
Department of Electrical Engineering	P.R. Belanger	N
Department of Electrical Engineering	C.H. Champness	N
Department of Electrical Engineering	G.W. Farnell	N
Department of Electrical Engineering	A.A. Gundjian	N
Department of Electrical Engineering	A.S. Hay	N
Department of Electrical Engineering	V. Hayward	N
Department of Electrical Engineering	C.K. Jen	N
Department of Electrical Engineering	M.D. Levine	N
Department of Electrical Engineering	A.S. Malowany	N
Department of Electrical Engineering	B.T. Ooi	N
Department of Electrical Engineering	J. Rajski	N
Department of Electrical Engineering	I.S. Shih	N
Department of Electrical Engineering	P.P. Silvester	N
Department of Electrical Engineering	G.L. Yip	N
Department of Electrical Engineering	P.O. Zucker	N
Department of Mechanical Engineering	M.G. Akben	N
Department of Mechanical Engineering	D.R. Axelrad	N
Department of Mechanical Engineering	L. Kops	N
Department of Mechanical Engineering	C.L. Murphy	N
Department of Mechanical Engineering	J.W. Provan	M
Department of Physics	Z. Altounian	N
Department of Physics	R. Harris	N
Department of Physics	W.B. Muir	N
Department of Physics	J.D. Strom-Olsen	B
Department of Physics	D. Walsh	B
Mining & Metallurgical Engineering	R.A.L. Drew	B
Mining & Metallurgical Engineering	J.E. Gruzleski	N
Mining & Metallurgical Engineering	R.I.L. Guthrie	N
Mining & Metallurgical Engineering	J.J. Jonas	N
Mining & Metallurgical Engineering	J.A. Szpunar	M
<i>McMaster University</i>		
Department of Chemical Engineering	J.L. Brash	N
Department of Chemical Engineering	A.E. Hamielec	B
Department of Chemical Engineering	J.F. MacGregor	N
Department of Chemical Engineering	P.A. Taylor	N
Department of Chemical Engineering	J. Vlachopoulos	N
Department of Chemical Engineering	P.E. Wood	N
Department of Chemical Engineering	D.R. Woods	N
Department of Chemical Engineering	J.D. Wright	N
Department of Chemistry	W.J. Leigh	N
Department of Chemistry	D.B. McLean	N
Department of Computer Science	D.R. Conn	N
Department of Engineering Physics	E.A. Ballik	N

University and Department	Name	Source
<i>McMaster University (cont'd)</i>		
Department of Engineering Physics	A.A. Berezin	B
Department of Engineering Physics	D.T. Cassidy	B
Department of Engineering Physics	J.A. Davies	N
Department of Engineering Physics	B.K. Garside	N
Department of Engineering Physics	P.E. Jessop	B
Department of Engineering Physics	J. Reid	N
Department of Engineering Physics	D.A. Thompson	B
Department of Materials Science	G.A. Irons	N
Department of Materials Science	A.H. Kitai	B
Department of Materials Science	P.S. Nicholson	B
Department of Materials Science	G.R. Piercey	B
Department of Materials Science	D.S. Wilkinson	N
Department of Mechanical Engineering	H.A. Elmaraghy	N
Department of Metals & Materials Science	J.D. Embury	N
Department of Metals & Materials Science	G.P. Johari	B
Department of Metals & Materials Science	G.R. Purdy	B
Department of Physics	A.J. Berlinsky	N
Department of Physics	I.D. Brown	N
Department of Physics	J.P. Carbotte	B
Department of Physics	W.R. Datars	N
Department of Physics	C.V. Stager	N
Electrical & Computer Engineering	C.K. Campbell	N
Electrical & Computer Engineering	D.W. Capson	N
Electrical & Computer Engineering	M.A.E. El-Kady	N
Institute for Materials Research	T. Birchall	M
Institute for Materials Research	J.S. Chang	M
Institute for Materials Research	P.T. Dawson	M
Institute for Materials Research	J.E. Greedan	M
Institute for Materials Research	A.P. Hitchcock	B
Institute for Materials Research	J.S. Kirkaldy	M
Institute for Materials Research	W.W. Smeltzer	M
Institute for Materials Research	S.V. Subramanian	M
<i>Memorial University</i>		
Department of Chemistry	P.G. Pickup	B
Department of Chemistry	F.R. Smith	M
Department of Mechanical Engineering	A.M. Sharan	N
Department of Physics	J.P. Whitehead	N
Department of Physics	M.D. Whitmore	N
<i>Queen's University</i>		
Department of Chemistry	W.E. Baker	B
Department of Chemistry	A. Natanaohn	M
Department of Chemistry	K.E. Russell	B
Department of Chemistry	J.K.S. Wan	N
Department of Electrical Engineering	M.M. Bayoumi	N
Department of Electrical Engineering	P.C. Sen	N

University and Department	Name	Source
<i>Queen's University (cont'd)</i>		
Department of Mechanical Engineering	J. Jeswiet	N
Department of Metallurgical Engineering	U. Erb	N
Department of Metallurgical Engineering	S. Saimoto	N
Department of Physics	D.L. Atherton	N
Department of Physics	M. Sayer	B
Department of Physics	P.J. Scanlon	M
Department of Physics	J.L. Whitton	B
School of Business	C.A. Beatty	N
<i>Simon Fraser University</i>		
Department of Chemistry	B.L. Punt	B
Department of Chemistry	I.D. Gay	M
Department of Chemistry	C.H.W. Jones	M
Department of Chemistry	L.K. Peterson	M
Department of Chemistry	R.K. Pomeroy	N
Department of Chemistry	A.S. Tracey	N
Department of Computer Science	T.W. Calvert	N
Department of Computer Science	H.K. Reghbatl	N
Department of Physics	A.S. Arrott	N
Department of Physics	L.E. Ballentine	N
Department of Physics	J.F. Cochran	B
Department of Physics	K. Colbow	B
Department of Physics	E.D. Crozier	M
Department of Physics	A.E. Curzon	M
Department of Physics	R.F. Frindt	M
Department of Physics	S. Gygax	M
Department of Physics	B. Heinrich	M
Department of Physics	J.C. Irwin	N
Department of Physics	S.R. Morrison	B
Department of Physics	M.L. Thewalt	B
Faculty of Engineering	J.K. Cavers	N
<i>St. Francis Xavier University</i>		
Department of Chemistry	E.A. Secco	N
Department of Physics	M.O. Steinitz	M
Department of Physics	A. Weingartshofer	N
<i>Technical University of Nova Scotia</i>		
Department of Electrical Engineering	M. Cada	B
Department of Engineering Physics	H.W. King	N
Department of Engineering Physics	J.G. Murphy	N
<i>Trent University</i>		
Department of Physics	A.J. Slavin	M

University and Department	Name	Source
<i>Université de Moncton</i>		
Département de génie	P. Labossière	B
Département de physique	F.E. Girouard	N
Département de physique	T. Vo-Van	N
<i>Université de Montréal</i>		
Département de chimie	A.L. Beauchamp	N
Département de chimie	F.R. Brisse	N
Département de chimie	D.R. Salahub	N
Département de physique	J.L. Brebner	N
Département de physique	R.W. Cochrane	N
Département de physique	J. Detry	N
Département de physique	J.Y. Harbec	N
Département de physique	M. Moisan	N
<i>Université du Québec à Chicoutimi</i>		
Département des sciences appliquées	P. Meubus	M
<i>Université du Québec à Montréal</i>		
Département de chimie	G.A. Capuano	B
Département de chimie	G. Delmas-Patterson	N
Department of Chemistry	D. Belanger	M
Department of Chemistry	G. Fortier	M
<i>Université du Québec à Rimouski</i>		
Groupe régional de support aux PME	J.-L. Chaumel	M
<i>Université du Québec à Trois Rivières</i>		
Centre de recherche en pâtes et papiers	R. Chen	M
Centre de recherche en pâtes et papiers	B.V. Kokta	M
Département recherche pâtes et papiers	C. Daneault	N
Département recherche pâtes et papiers	B.V. Kokta	N
Ingénierie	R. Chen	N
Ingénierie	K. Ghosh	N
Photobiophysique	R.M. Leblanc	N
<i>Université de Sherbrooke</i>		
Département de chimie	A.D. Bandrauk	N
Département de chimie	J. Lessard	N
Département de génie chimique	M.I. Boulos	B
Département de génie chimique	E. Chornet	B
Département de génie civil	P.C. Altin	B
Département de génie civil	G. Ballivy	N
Département de génie civil	K.W. Neale	N
Département de physique	M.M. Aubin	N

University and Department	Name	Source
<i>Université de Sherbrooke (cont'd)</i>		
Département de physique	C. Carlone	N
Département de physique	L.G. Caron	N
Département de physique	J.D.N. Cheeke	N
Département de physique	M.M. Perlman	N
Département de physique	M. Poirier	N
Department of Mechanical Engineering	C. Roy	B
<i>Université Laval</i>		
Département de chimie	G.G. Bazuin	B
Département de chimie	G. Charlet	B
Département de chimie	J.W. Leonard	B
Département de génie chimique	A. Ait-Kadi	B
Département de génie chimique	L. Choplin	N
Département de génie chimique	S.C.F. Kaliaguine	N
Département de génie chimique	P.A. Tanguy	B
Département de génie électrique	H. Le-Juy	N
Département de génie électrique	M. Tetu	N
Département de génie mécanique	R.G. Prud'homme	B
Département de physique	P.A. Belanger	N
Département de physique	G. Boivin	B
Département de physique	S.L. Chin	B
Département de physique	Galarneau	M
Département de physique	H. Jeronimek	B
Département de physique	Knystautas	M
Département de physique	Lessard	M
Département de physique	N. McCarthy	B
Département de physique	M. Piche	N
Département de physique	R. Tremblay	B
Département de science et génie	B. Riedl	B
Mines et métallurgie	R.H. Angers	N
Mines et métallurgie	A. Galibois	N
<i>University of Alberta</i>		
Department of Electrical Engineering	H.P. Baltes	N
Department of Electrical Engineering	M.J. Brett	N
Department of Electrical Engineering	C.E. Capjack	N
Department of Electrical Engineering	C.G. Englefield	N
Department of Electrical Engineering	R. Fedosejevs	N
Department of Electrical Engineering	I. Filanovsky	N
Department of Electrical Engineering	V. Gourishankar	N
Department of Electrical Engineering	C.R. James	N
Department of Electrical Engineering	R.P.W. Lawson	N
Department of Electrical Engineering	J.N. McMullin	N
Department of Electrical Engineering	A.A. Offenberger	N
Department of Electrical Engineering	L. Ristic	N
Department of Electrical Engineering	H.G. Schmidt-Weinmar	N
Department of Electrical Engineering	H.J.J. Sequin	N

University and Department	Name	Source
<i>University of Alberta (cont'd)</i>		
Department of Electrical Engineering	J. Tušip	N
Department of Mechanical Engineering	D.G. Bellow	M
Department of Mechanical Engineering	F. Ellyin	M
Department of Mineral Engineering	T.H. Ettell	B
Department of Physics	Z. Gortel	N
Department of Physics	B.V. Paranjape	N
Department of Restorative Dentistry	J. Wolfaardt	M
Mining, Metallurgical & Petroleum Engineering	R.L. Eadie	M
Mining, Metallurgical & Petroleum Engineering	D.G. Ivey	B
<i>University of British Columbia</i>		
Department of Chemistry	F. Aubke	N
Department of Chemistry	G.S. Bates	B
Department of Chemistry	D.E. Brooks	M
Department of Chemistry	M.D. Fryzak	N
Department of Chemistry	F.G. Herring	M
Department of Chemistry	K.A.R. Mitchell	B
Department of Chemistry	E.A. Ogryzlo	B
Department of Chemistry	R.C. Thompson	M
Department of Civil Engineering	R.J. Gray	N
Department of Civil Engineering	S. Mindess	M
Department of Computer Science	A.K. Mackworth	N
Department of Electrical Engineering	W.G. Dumont	N
Department of Electrical Engineering	M.R. Ito	N
Department of Electrical Engineering	P.D. Lawrence	N
Department of Electrical Engineering	D.L. Pulfrey	N
Department of Electrical Engineering	L. Young	N
Department of Mechanical Engineering	D.B. Cherchas	N
Department of Metallurgical Engineering	A.C.D. Chaklader	B
Department of Metallurgical Engineering	E.B. Hawbolt	B
Department of Metallurgical Engineering	J.A.H. Lund	B
Department of Metallurgical Engineering	A. Mitchell	B
Department of Metallurgical Engineering	A. Poursartip	B
Department of Metallurgical Engineering	I.V. Samarasekera	N
Department of Metallurgical Engineering	E. Teghtsoonian	B
Department of Metallurgical Engineering	F. Weinberg	B
Department of Physics	R.W. Cline	N
Department of Physics	J.E. Eldridge	N
Department of Physics	R.R. Haering	N
Department of Physics	J. Meyer	N
Department of Physics	A.K.H. Ng	N
Department of Physics	P. Palffy-Muhoray	N
Department of Physics	R.R. Parsons	N
Department of Physics	C.F. Schwerdtfeger	N
Department of Physics	J.T. Tiedje	N
Department of Physics	D.L. Williams	N
Metals and Materials Engineering	L.C. Brown	M

University and Department	Name	Source
<i>University of Calgary</i>		
Department of Chemistry	T.G. Back	N
Department of Chemistry	V.I. Birss	N
Department of Civil Engineering	C.D. Johnston	N
Department of Computer Science	J. Kendall	N
Department of Electrical Engineering	W.C. Chan	N
Department of Electrical Engineering	J.W. Haslett	N
Department of Mechanical Engineering	D.H. Norrie	N
Department of Mechanical Engineering	W.J.D. Shaw	M
<i>University of Guelph</i>		
Department of Chemistry and Biochemistry	E.C. Alyea	N
Department of Chemistry and Biochemistry	M. Cocivera	N
Department of Chemistry and Biochemistry	J. Lipkowski	N
Department of Physics	P.A. Egelstaff	N
Department of Physics	C.W. Fischer	N
Department of Physics	B.G. Nickel	N
Department of Physics	J.R. Stevens	N
<i>University of Manitoba</i>		
Department of Chemistry	E. Bock	N
Department of Chemistry	A.F. Janzen	N
Department of Computer Science	D.M. Miller	N
Department of Electrical Engineering	H.C. Card	B
Department of Electrical Engineering	I.M.R. Ciric	N
Department of Electrical Engineering	K.C. Kao	N
Department of Electrical Engineering	R.D. McLeod	N
Department of Electrical Engineering	D.J. Thomson	N
Department of Electrical Engineering	M. Vaisey-Genser	N
Department of Mechanical Engineering	S. Balakrishnan	N
Department of Mechanical Engineering	J.R. Cahoon	N
Department of Mechanical Engineering	M.C. Chaturvedi	N
Department of Mechanical Engineering	K. Tangri	N
Department of Physics	P. Gaunt	N
Department of Physics	A.H. Morrish	N
<i>University of New Brunswick</i>		
Department of Chemical Engineering	D.M. Ruthven	N
Department of Chemistry	F. Bottomley	N
Department of Chemistry	J. Passmore	N
Department of Electrical Engineering	R. Doraiswami	N
Department of Electrical Engineering	M.E. Kaye	N
Department of Forest Resources	M.H. Schneider	N
Department of Mechanical Engineering	J.G. Lenard	M
Department of Mechanical Engineering	R.J. Rogers	M
Department of Mechanical Engineering	A.C.M. Sousa	M
Department of Mechanical Engineering	J.E.S. Venart	M
Department of Physics	C.H. Leung	N

University and Department	Name	Source
<i>University of Ottawa</i>		
Department of Chemical Engineering	E. Mitsoulis	N
Department of Chemistry	H. Alper	N
Department of Chemistry	B.E. Conway	N
Department of Chemistry	J.M.J. Frechet	N
Department of Computer Science	R.L. Probert	N
Department of Electrical Engineering	S.R. Das	N
Department of Electrical Engineering	D.T. Gibbons	N
Department of Electrical Engineering	M. Goldberg	N
Department of Electrical Engineering	W.J.R. Hoefer	N
Department of Electrical Engineering	W.F. McGee	N
Department of Electrical Engineering	E. Petriu	N
Department of Mechanical Engineering	A.E.F. Fahim	N
Department of Mechanical Engineering	Y.M. Haddad	B
Department of Mechanical Engineering	A.S. Krause	M
Department of Mechanical Engineering	M.B. Munro	B
Department of Physics	P. Bernard	N
Department of Physics	E. Fortin	N
Department of Physics	B. Joos	N
Department of Physics	J.L.G. Lamarche	N
Department of Physics	M.A.R. Le Blanc	N
Department of Physics	D.G. Rancourt	M
Department of Physics	A.K.S. Song	N
Department of Physics	J.C. Wooley	N
<i>University of Regina</i>		
Faculty of Engineering	E.H. Hara	N
<i>University of Saskatchewan</i>		
Department of Chemical Engineering	M.N. Esmail	N
Department of Chemistry	P.G. Mezey	N
Department of Chemistry	W.L. Waltz	N
Department of Electrical Engineering	S.D. Kasap	B
Department of Electrical Engineering	S. Kumar	N
Department of Mechanical Engineering	H.T. Danyluk	N
<i>University of Toronto</i>		
Aerospace Institute	A.A. Haasz	B
Aerospace Institute	R.M. Measures	B
Aerospace Institute	N. Salansky	M
Aerospace Institute	R.C. Tennyson	B
Aerospace Studies	G.M.T. D'Eleutorio	N
Aerospace Studies	J.S. Hansen	N
Aerospace Studies	P.C. Hughes	N
Chemical Engineering and Applied Chemistry	S.T. Balke	M
Chemical Engineering and Applied Chemistry	C.E. Chaffey	M
Chemical Engineering and Applied Chemistry	M.R. Piggott	B

University and Department	Name	Source
<i>University of Toronto (cont'd)</i>		
Chemical Engineering and Applied Chemistry	R.T. Woodhams	B
Department of Chemical Engineering	H.L. Williams	N
Department of Chemistry	A.G. Brooke	N
Department of Chemistry	M.J. Dignam	N
Department of Chemistry	D.H. Farrar	N
Department of Chemistry	J.E. Guillet	N
Department of Chemistry	U.J. Krull	N
Department of Chemistry	M. Moskovits	N
Department of Chemistry	G.A. Ozin	B
Department of Chemistry	J.C. Polyani	N
Department of Chemistry	W.F. Reynolds	N
Department of Chemistry	M. Thompson	N
Department of Chemistry	S.C. Wallace	N
Department of Chemistry	S.G. Whittington	N
Department of Chemistry	M.A. Winnik	B
Department of Civil Engineering	R.D. Hooton	M
Department of Civil Engineering	R.H. Mills	M
Department of Computer Science	R.M. Baecker	N
Department of Electrical Engineering	P.P. Biringer	N
Department of Electrical Engineering	W.L. Cleghorn	N
Department of Electrical Engineering	J.D. Lavers	N
Department of Electrical Engineering	P. Ratnam	N
Department of Electrical Engineering	W.M. Ristic	N
Department of Electrical Engineering	C.A.T. Salama	N
Department of Electrical Engineering	W.M. Snelgrove	N
Department of Electrical Engineering	S. Zukotynski	N
Department of Mechanical Engineering	A.A. Goldenberg	N
Department of Mechanical Engineering	A. Mandelis	N
Department of Mechanical Engineering	D. McCammond	N
Department of Mechanical Engineering	A.N. Sinclair	N
Department of Physics	J.M. Perz	N
Department of Physics	J.E. Sipe	N
Department of Physics	B.P. Stoicheff	N
Department of Physics	J. Timusk	N
Department of Physics	H.M. Van Driel	N
Department of Survey Sciences	A.M. Wassef	N
Metallurgy and Materials Science	C.B. Alcock	N
Metallurgy and Materials Science	K.T. Aust	B
Metallurgy and Materials Science	S.N. Flengas	N
Metallurgy and Materials Science	J.M. Lee	M
Metallurgy and Materials Science	A. McLean	N
Metallurgy and Materials Science	W.A. Miller	N
Metallurgy and Materials Science	T.H. North	N
Metallurgy and Materials Science	A.R. Perrin	B
Metallurgy and Materials Science	R.M. Pilliar	M
Metallurgy and Materials Science	J.W. Rutter	N
Metallurgy and Materials Science	I.D. Sommerville	N
Metallurgy and Materials Science	S.J. Thorpe	B
Metallurgy and Materials Science	G.C. Weatherly	M

University and Department	Name	Source
<i>University of Victoria</i>		
Department of Chemistry	T.M. Fyles	M
Department of Chemistry	D.A. Harrington	M
Department of Chemistry	R.N. O'Brien	M
Department of Electrical Engineering	R. Vahldieck	N
<i>University of Waterloo</i>		
Department of Chemical Engineering	C.M. Burns	N
Department of Chemical Engineering	R.Y.M. Huang	N
Department of Chemical Engineering	G.L. Rempel	N
Department of Chemistry	A.J. Carty	B
Department of Chemistry	M.J. Chong	N
Department of Chemistry	T.E. Gough	N
Department of Chemistry	D.A. Holden	B
Department of Chemistry	D.E. Irish	B
Department of Chemistry	L.F. Nazar	M
Department of Chemistry	K.F. O'Driscoll	M
Department of Chemistry	L.W. Reeves	M
Department of Chemistry	A. Rudin	B
Department of Chemistry	M. Tchir	M
Department of Civil Engineering	D.E. Grierson	N
Department of Civil Engineering	J.T. Pindera	N
Department of Computer Science	J.I. Munro	N
Department of Electrical Engineering	S.G. Chamberlain	N
Department of Electrical Engineering	J.D. Cross	N
Department of Electrical Engineering	M.I. Elmasry	N
Department of Electrical Engineering	J.W. Mark	N
Department of Electrical Engineering	D.J. Rouston	N
Department of Electrical Engineering	R.E. Seviara	N
Department of Electrical Engineering	J. Vlach	N
Department of Electrical Engineering	W.J. Wilson	N
Department of Management Sciences	J.A. Buzacott	N
Department of Mathematics	W.R. Pulleyblank	N
Department of Mechanical Engineering	K.G. Adams	N
Department of Mechanical Engineering	J.P. Huissoon	N
Department of Mechanical Engineering	H.W. Kerr	M
Department of Mechanical Engineering	K. Piekarski	N
Department of Mechanical Engineering	Y. Stepanenko	N
Department of Mechanical Engineering	R.A. Varin	B
Department of Mechanical Engineering	D.C. Weckman	M
Department of Mechanical Engineering	M.M. Yovanovich	N
Department of Physics	F.W. Boswell	B
Department of Physics	D.E. Brodie	B
Department of Physics	J.M. Corbett	N
Department of Physics	A.E. Dixon	N
Department of Physics	N.R. Isenor	N
Department of Physics	J.D. Leslie	M
Department of Physics	A.D.S. Nagi	N
Department of Physics	J.L. Ord	N
Department of Physics	M.M. Pintar	M
Department of Physics	G.A. Scholz	B
Department of Physics	J.H.T. Smith	N

University and Department	Name	Source
<i>University of Western Ontario</i>		
Department of Applied Mathematics	M.A. Nerenberg	N
Department of Chemical Engineering	H.I. De Lasa	N
Department of Chemistry	P.W.M. Jacobs	N
Department of Chemistry	N.S. McIntyre	N
Department of Chemistry	P.R. Norton	N
Department of Chemistry	R.J. Puddephatt	N
Department of Chemistry and Physics	I.V. Mitchell	B
Department of Electrical Engineering	W.D. Greason	N
Department of Engineering Materials	J.D. Brown	N
Department of Engineering Materials	W.M. Lau	N
Department of Engineering Materials	D.M. Shinozaki	N
Department of Physics	E. Brannen	N
Department of Physics	P.K. John	N
Department of Physics	M. Singh	N
Department of Physics	B.Y.P. Tong	N
Department of Restorative Dentistry	L.N. Johnson	N
<i>University of Windsor</i>		
Department of Chemical Engineering	D.C.R. DeKee	N
Department of Electrical Engineering	E.A. Cherney	N
Department of Electrical Engineering	A. Watson	N
Department of Engineering Materials	D.O. Northwood	M
Department of Engineering Materials	D.F. Watt	M
Department of Engineering Materials	H. Yamauchi	B
Department of Engineering Materials	W.V. Youdelis	M
<i>University of Winnipeg</i>		
Department of Mechanical Engineering	D.P. Kerr	N
Department of Physics	S. Dannefaer	M
Department of Physics	E. Tomchuk	N
<i>Wilfred Laurier University</i>		
Department of Physics	J. Lit	N
<i>York University</i>		
Department of Chemistry	S.V. Filseth	N
Department of Chemistry	A.P.B. Lever	N
Department of Mathematics	C.K. Hruska	N
Department of Physics	W.W. Duley	M

Appendix B

Sample Letters and Questionnaires

The "Research Letter"



CENTRE FOR
RESOURCE STUDIES
(613) 545-2553

Queens University
Kingston, Canada
K7L 3N6

June 1, 1990

Dr.
Department of Civil Engineering ,
Carleton University
Ottawa, Ontario, K1S 5B6

Dear

In 1987, a number of reports were prepared by different organizations which attempted to document the state of "Advanced Industrial Materials" (AIM) research in Canada. Unfortunately, the results of the studies were not directly comparable. That performed by NSERC included research supported by NSERC which was identified by use of the "Areas of application code" submitted with the grant applications. At the same time, the Ministry of State for Science and Technology (MOSST) carried out an independent study which classified the research using different criteria.

The picture that emerged was clouded. The Centre for Resource Studies (CRS) at Queen's University has undertaken to attempt the rationalization of the data. The results will be presented in a report to Industry, Science and Technology Canada (ISTC - the successor to MOSST) documenting the state of AIM research in Canadian universities. This report will be used as part of the planning material for decisions regarding funding support and as a benchmark against which future progress and development can be measured.

To avoid having to recollect all the data, it has been decided to request verification of existing information and its classification on a sample basis. There is no obligation to participate in the study and responses are to be provided on a voluntary basis. However, in the interests of the future of research in AIM, the widest possible participation is encouraged. The update will be concerned with UNIVERSITY research in AIM only and three questions are to be addressed. These concern classification of research projects, numbers of students involved in the study of AIM and determination of the degree of incorporation of the results of AIM research into university curricula.

Data taken from available sources suggest that you are active in one or more areas of AIM research. The attached sheet shows the titles of projects which our source material suggests you were involved with during 1987. I would appreciate it if you would verify the data by providing the data requested on the form.

A follow-up visit to your university is planned early in 1990 to obtain information on the other questions referred to above. On a separate sheet is a possible schedule for visiting your university. In order to arrange this visit at a time most acceptable to you, I would appreciate it if you would indicate whether the time frame is acceptable to you, suggest possible alternatives if it is not, and return this information with the other questionnaire.

The request form has been designed to require as little of your valuable time as possible. Your cooperation in providing this information will allow CRS to function more effectively in preparing this report and in suggesting means by which research in AIM can be aided most effectively.

If questions arise, please contact either M. Wojciechowski at CRS (613-545-2553) or J. McIntosh at ISTC (613-993-6280). Please return the information to CRS at the address shown on the letterhead.

Thank you for your cooperation.

Sincerely,

M. Wojciechowski,
Executive Director, CRS

AREAS OF "AIM"

<u>CODE</u>	<u>AREA</u>
CER	ceramics, glasses and refractories
COA	coatings, surfaces and interfaces
COM	composites and compound materials
FIB	fibre optic and laser materials and technologies
LIQ	liquid crystal materials and applications
MET	metals and alloys
PHO	photovoltaic materials
POL	polymeric materials and processes
SEM	semiconductor materials and technologies
ROB	robotics and systems materials and technologies [automation, CAD/CAM/CAE etc]
DES	end product design using advanced industrial materials

REQUEST FORM

1. Indicate if the project titles and funding totals given are accurate and give corrections where required. [use the grant application or the contract title]
2. From the list of eleven classifications shown on the previous page, indicate which ONE or TWO best describe the areas of most intense interest and investigation. If more than one descriptor is appropriate, rank these in order of importance (1=highest).

NOTE: The inclusion of the noted projects into one of the various source lists in many cases reflects the opinion of one person who may or may not be expert in your area. If you do not consider any of the projects noted to be correctly considered as part of Advanced Industrial Materials Research, please indicate this on the form.

3. If funding is jointly provided by several sources, indicate the approximate percentage provided by each source. The term "industry" is used to protect proprietary information. If the funding was for several years, please give the approximate ANNUAL figure.
4. In the blank space provided, please indicate the percentage increase or decrease since 1987 in your research funding for projects which fall in one or more of the categories indicated on the previous page.

% increase (decrease) in ANNUAL AIM-related research funding since 1987 -

<u>Project Title</u>	<u>1987 Annual Funding (\$000)</u>	<u>% Contribution</u> (NSERC/Industry/Other)	<u>Code 1</u> <u>Code 2</u>
Fracture mechanics of brittle multiphase materials	20		
Numerical modelling of fracture and interface phenomena	20		
Transient thermoelastic fracture mechanics	23		

The "Student Letter"



CENTRE FOR
RESOURCE STUDIES
(613) 545-2553

Queens University
Kingston, Canada
K7L 3N6

June 1, 1990

Head, Department of Electrical Engineering
Concordia University
1455 de Maisonneuve Blvd. West,
Montreal, Quebec, H3G 1M8

Dear Sir:

The Centre for Resource Studies (CRS) at Queen's University has undertaken to update studies done by the Ministry of State for Science and Technology (MOSST) and NSERC in 1987 concerning research in ADVANCED INDUSTRIAL MATERIALS (AIM) in Canadian universities. The results will be presented as a report to Industry, Science and Technology Canada (ISTC, the successor to MOSST) documenting the state of AIM research in Canada. This report will be used as part of the planning material for decisions regarding funding support and as a benchmark against which future progress and development may be measured.

A vital part of this study is information on the numbers of students who are engaged in graduate studies in this area. Our source material indicates that your department is engaged in research in this area. The completion of the study will be aided immensely if you would provide the information requested below. There is no obligation to participate in the study and responses are to be provided on a voluntary basis. However, in the interests of the future of research in AIM, the widest possible participation is encouraged. The request is designed to require as little of your valuable time as possible.

Since our source material is drawn from several different places, it is possible you will receive two requests for the same material. If this occurs, please return the duplicate questionnaires so that we can correct our lists.

Your cooperation in the study will allow CRS to function more effectively on your behalf in collecting this information and in suggesting means by which research in AIM can be aided most effectively.

If questions arise, please contact either M. Wojciechowski at CRS (613-545-2553) or J. McIntosh at ISTC (613-993-6280). Please return the information to CRS at the address shown on the letterhead.

Thank you for your cooperation.

Sincerely,

M. Wojciechowski,
Executive Director, CRS.

AREAS OF "AIM"

<u>CODE</u>	<u>AREA</u>
CER	ceramics, glasses and refractories
COA	coatings, surfaces and interfaces
COM	composites and compound materials
FIB	fibre optic and laser materials and technologies
LIQ	liquid crystal materials and applications
MET	metals and alloys
PHO	photovoltaic materials
POL	polymeric materials and processes
SEM	semiconductor materials and technologies
ROB	robotics and systems materials and technologies [automation, CAD/CAM/CAE etc]
DES	end product design using advanced industrial materials

INFORMATION REQUESTED

1. Please list the **NAMES, THESIS TITLE** (if known) and **CODE** from the attached list of all current graduate students who are enrolled in a **Ph.D.** program which should be considered as part of Advanced Industrial Materials research. If more than one code appears applicable please rank the importance of these (1=highest). The names of the students are required for cross-checking only. Only aggregate numbers will be supplied to the **ISTC**.
2. Indicate the **NUMBER OF POSTDOCTORAL FELLOWS** or **RESEARCH ASSOCIATES** currently working in this area in your department. The **NSERC** definitions for these positions should be used. Please do **NOT** include individuals with permanent positions (e.g. technicians)
3. Listed below are the names of faculty in your department which our source material suggests were active in AIM research in 1987. Please make any required deletions or additions which are necessary to reflect the true situation at that time.

Dimopoulos, N.J.

Ziogas, P.D.

Faruque, S.M.

Hayes, J.F.

Lombos, B.A.

Schwelb, O.

The Follow-up Student Letter



CENTRE FOR
RESOURCE STUDIES
(613) 545-2553

Queen's University
Kingston, Canada

January 23, 1990

Head, Department of Mechanical Engineering
McGill University
845 Sherbrooke St. West,
Montreal, Quebec, H3A 2T5

Dear Sir:

In November 1989, you received a request from the Centre for Resource Studies (CRS) at Queen's University for information regarding faculty in your department who are active in the area of "Advanced Industrial Materials" (AIM) and students who are currently pursuing graduate studies in this area. As of this date, we have not received a response from you and I am writing to solicit your assistance in making the compilation of human resources in this area as complete as possible.

It is clear that the assembly of student names and thesis titles which was originally requested is a more onerous task than we had realized. Therefore, as you will see from the attached, we have reduced the scope of our request significantly in the hope and expectation that you will find it more feasible to supply the information. In order to expedite the return of the information, it may be either mailed or FAXed to me at the following address:

ISTC, Room 835E,
235 Queen St, Ottawa, Ont. K1A 0H5
FAX (613)-996-7887

For your information the codes which define the areas of AIM are shown below.

I thank you in advance for your cooperation.

Sincerely,

John M. McIntosh

AREAS OF "AIM"

<u>CODE</u>	<u>AREA</u>
CER	ceramics, glasses and refractories
COA	coatings, surfaces and interfaces
COM	composites and compound materials
FIB	fibre optic and laser materials and technologies
LIQ	liquid crystal materials and applications
MET	metals and alloys
PHO	photovoltaic materials
POL	polymeric materials and processes
SEM	semiconductor materials and technologies
ROB	robotics and systems materials and technologies [automation, CAD/CAM/CAE etc]
DES	end product design using advanced industrial material

McGill University, Department of Mechanical Engineering

TOTAL number of GRADUATE students involved in AIM research
who are currently registered in a M.Sc. Program.

Number of GRADUATE students involved in AIM research
who are currently registered in a M.Sc. Program.
and WHO ARE IN CANADA ON STUDENT VISAS

TOTAL number of GRADUATE students involved in AIM research
who are currently registered in a Ph.D. Program.

Number of GRADUATE students involved in AIM research
who are currently registered in a Ph.D. Program.
and WHO ARE IN CANADA ON STUDENT VISAS

An ESTIMATE of the percentage of students who normally
pursue Ph.D. studies (either at your university or elsewhere)
directly after completing a M.Sc. degree

_____ %

Listed below are the names of faculty in your department which our source material suggests were active in AIM research in 1987. Please verify this information and add any names of faculty (with the codes of their major area of interest) that have joined your department since that time.

Akben, M.G.

Axelrad, D.R.

Kops, L.

Murphy, C.L.

Provan, J.W.

Appendix C

Additions and Deletions

The additions represent a collection of names gathered during this study in many different ways and from a variety of sources. No effort has been made to verify that these individuals are truly involved in materials-related research, nor is it suggested that this list is comprehensive. Likewise these individuals may not have been at these institutions or engaged in AIM research in 1987. This list, therefore, does not meet the criteria set out for the Composite List in Appendix A.

The deletions are likewise the result of information received in the course of this study.

Additions

Department/Faculty	Additions
<i>Carleton University</i>	
Department of Civil Engineering	A.O.A. Halim, J.L. Human, A.G. Razagpur, J. Salinas
Department of Electronics	Nakhla, D. Walkey,
Department of Mechanical Engineering	Goldak, McGill
<i>Dalhousie University</i>	
Department of Physics	D. Labrie, G. Stroink
Faculty of Dentistry	Jones
<i>École Polytechnique de Montréal</i>	
Département de génie chimique	Lafleur
Département de génie mécanique	M. Benabdallah, B. Sanschagrin
Département de génie métallurgique	F. Ajerach, Bailon, J.M. Dorlot, D.L.P. Piron, Y. Verreman
<i>Lakehead University</i>	
Department of Physics	Sears
Faculty of Engineering	Singh
<i>McGill University</i>	
Department of Chemistry	G. Darling, E. Salin, A. Shaver, D.J. Simkin
Department of Electrical Engineering	L. Daneshmend, F. Ferrie, D. Lowther, N. Rumin, J. Webb
Mining & Metallurgical Engineering	Yue
<i>McMaster University</i>	
Department of Chemical Engineering	J.M. Dickson, A.N. Hrymak, R.H. Pelton
Department of Chemistry	J. Barbier, M.A. Brooke, R.F. Childs, H. Stover
Department of Engineering Physics	J.S. Preston, J.G. Simmons
Department of Materials Science & Engineering	Z. Basinski, M.B. Ives, D.A.R. Kay, W.K. Lu, Petric, Weatherly
<i>Queen's University</i>	
Department of Chemical Engineering	C.C. Hsu, B. Wojciechowski
Department of Chemistry	M.C. Baird, B.K. Hunter, V.H. Smith
Department of Civil Engineering	B. Hope
Department of Electrical Engineering	D.O. Yevick
Department of Mechanical Engineering	T. Moore, H. Wevers

Department/Faculty	Additions
<i>Queen's University (cont'd)</i>	
Department of Metallurgical Engineering	J.D. Boyd, J. Cameron, U. Erb, C.M. Hansson, V.D. Kristic, C.A. Pickles, J.D. Shirkhanzadeh, R. Smith, C.M. Hansson
Department of Physics	D. Amm, A.B. McLean, M. Singh
Faculty of Medicine	T.V.D. Cooke
School of Business	J.R.M. Gordon, P.R. Richardson
<i>Simon Fraser University</i>	
Department of Chemistry	Holdcroft
Department of Computer Science	Hobson
Engineering	Rawicz
Physics	Dahn
<i>Trent University</i>	
Department of Physics	Londry
<i>Université de Moncton</i>	
Département de physique	P.V. Ashrit, G. Bader
<i>Université de Montréal</i>	
Département de chimie	Frud'homme
Département de physique	L.-A. Hamel, R. Leonelli, L. Lewis
<i>Université du Québec à Montréal</i>	
Département de chimie	Masrsan
<i>Université de Sherbrooke</i>	
Département de chimie	C. Jolicœur, M. Menard
Département de génie chimique	DeKee
Département de génie civil	S.L. Sarkar
Département de physique	Jandl
<i>Université Laval</i>	
Département de génie civil	N. Banthia, M. Pigeon
Département de génie électrique	M. Duguay, D. Laudandau, X. Maldague, F. Ouellette, D. Poussart
Département de mines et métallurgie	M.R. Krishnadev, R. Tremblay
Département de science du bois	Foliquin

Department/Faculty	Additions
<i>University of Alberta</i>	
Department of Chemical Engineering	K.T. Chuang, K.G. Dalla Lana, D.T. Lynch, S.E. Wanke
Department of Civil Engineering	K.O. Anderson, J.J. Cheng, E.L. Fowler, D.W. Macgregor, D.W. Murray, J.D. Scott, D.C. Sego, S.H. Simmonds
Department of Mechanical Engineering	D.R. Budney, M.G. Faulkner
Department of Physics	J.G. Adler, F.L. Weichman
Department of Restorative Dentistry Engineering	Dederich Otto
Mining, Metallurgical & Petroleum	S.A. Bradford, B.M. Patchett, A.C. Pierre
<i>University of British Columbia</i>	
Department of Chemistry	Fyfe
Department of Electrical Engineering	D. Camporese, N.A.F. Jaeger, C. Lazlo, C. Ma, D. Srivistava, K.D. Yedlin
Department of Metals & Materials	T.W. Alden, P.V. Barr, J.K. Brimacombe, D.B. Dreisinger, E. Peters, G.G. Richards, C.E. Schvezov, D. Tromas,
Department of Physics	Turekk
Unknown	Miller
<i>University of Calgary</i>	
Department of Civil Engineering	J.E. Gillott, R.C. Joshi, R.L. Day, M.A. Ward, B.W. Langan, N.G. Shrive
Department of Electrical Engineering	F.N. Trofimenkoff, A. Eldin, K. Kalen
Department of Mechanical Engineering	Mao
<i>University of Guelph</i>	
Department of Chemistry & Biochemistry	Baker
<i>University of Manitoba</i>	
Department of Civil Engineering	E.K. Attiogbe, S. Rizkalla
Department of Mechanical Engineering	N.W. Bassim
Department of Physics	J.S.C. McKee, R.M. Roshko
Unknown	Chatavedi
<i>University of New Brunswick</i>	
Department of Civil Engineering	T. Bremner
<i>University of Ottawa</i>	
Department of Civil Engineering	J.J. Beaudoin, J. Gardiner
Department of Electrical Engineering	Kavehrad
Department of Mechanical Engineering	Abken

Department/Faculty	Additions
<i>University of Regina</i>	
Unknown	Bohle, van Vleet
<i>University of Saskatchewan</i>	
Department of Chemical Engineering	Postlethwaite
Department of Civil Engineering	K. Nasser
Department of Mechanical Engineering	Yanocopoulos
<i>University of Toronto</i>	
Chemical Engineering and Applied Chemistry	D. Barham, Y.-L. Cheng, T. Coyle, M.T. Kortschot, Sefton, H.N. Tran
Department of Chemistry	S.C. Wallace, S.G. Whittington, M.A. Winnik
Department of Civil Engineering	Detweiler
Department of Electrical Engineering	Xu
Faculty of Dentistry	Smith
Unknown	Altus, Argyropoulos, Pritzker Toguri, Vaneso, Zingg
<i>University of Victoria</i>	
Department of Electrical Engineering	P. Agathoklis, J. Bornemann, N. Dimopoulos, H. Kwok, K.F. Li, W.S. Lu
<i>University of Waterloo</i>	
Department of Applied Mathematics	Lookman
Department of Civil Engineering	J.C. Thompson, T.M. Topper
Electrical & Computer Engineering	S.K. Chaudhuri, E.L. Heasell, W.P. Huang, A. Nathan, G. Pang, C.R. Selvakumar, R.G. van Heeswijk
<i>University of Western Ontario</i>	
Department of Chemistry	Bancroft
Department of Electrical Engineering	Kocerovsky
Department of Materials Engineering	J.S. Sheesby, P.J. Tumidajski
Unknown	Boughner
<i>University of Windsor</i>	
Department of Civil Engineering	C. MacInnes
Department of Geology	P. Hudec
<i>York University</i>	
Department of Physics	R.H. Prince, K.Y. Szeto

Deletions

Department	Deletions (Duplicates & Misidentification)
<i>Concordia University</i>	
Department of Electrical & Computer Eng.	Dimopoulos, S.M. Faruque, O. Schelb
<i>École Polytechnique de Montréal</i>	
Département de génie chimique	C. Chavarie, M. Meunier
Département de génie mécanique	A. Bazargui, T. Bui-Quoc, J.-M. Dorolot, Y. Verreman
Département de métallurgie	L.R. Cutler
<i>McGill University</i>	
Department of Chemistry	L. St. Pierre
Department of Electrical Engineering	V.K. Agarwal, B.T. Ooi
<i>McMaster University</i>	
Department of Computer Science	D.R. Conn
Department of Engineering Physics	B.K. Garside
<i>Simon Fraser University</i>	
Department of Computer Science	H.K. Reghbatti
Department of Physics	L.E. Ballentine, J.C. Irwin
Faculty of Engineering	J.K. Cavers
<i>Université de Montréal</i>	
Département de chimie	F.R. Brisse
Département de physique	J.Y. Harbec
<i>Université du Québec à Montréal</i>	
Département de chimie	G. Fortier
<i>Université du Québec à Trois Rivières</i>	
Département de recherche en pâtes	C. Dancault
<i>Université Laval</i>	
Département de génie électrique	H. Le Huy
Département de génie mécanique	R.G. Prud'homme

Department	Deletions (Duplicates & Misidentification)
<i>University of Alberta</i>	
Department of Electrical Engineering	H.P. Baltes, C.E. Capjack, C.G. Englefield, R. Pedosejeva, I. Filanovsky, V. Gourishanker, C.R. James, J.N. McMullin, A.A. Offenberger, H.G. Schmidt-Weinmar, J. Tulip, Z. Gortel, B.V. Paranjape
Department of Physics	
<i>University of British Columbia</i>	
Department of Chemistry	G.S. Bates, D.E. Brooks, M.D. Fryzuk, D.E. Herring
Department of Civil Engineering	R. Gray
Department of Metallurgical Engineering	E. Teghtasounian
Department of Physics	P. Falffy-Muhoray
<i>University of Calgary</i>	
Department of Chemistry	T.G. Back, V.I. Birs
Department of Computer Science	J. Kendall
Department of Electrical Engineering	W.C. Chan
<i>University of Guelph</i>	
Department of Physics	B. Nickel
<i>University of Manitoba</i>	
Department of Electrical Engineering	H.C. Card, H.C. Ciric, R.D. McLeod, M. Vaisey-Genser
Department of Physics	P. Gaunt
<i>University of New Brunswick</i>	
Department of Chemistry	F. Bottomley, F. Passmore,
Department of Chemical Engineering	D.M. Ruthven
Department of Mechanical Engineering	J.G. Lenard, R.J. Rogers, A.C.M. Sousa
<i>University of Ottawa</i>	
Department of Electrical Engineering	M. Goldberg, W.F. McGee, E. Petriu
<i>University of Saskatchewan</i>	
Department of Chemistry	W.L. Waltz
Department of Electrical Engineering	S.D. Kumar
Department of Mechanical Engineering	H.T. Danyluk

Department	Deletions (Duplicates & Misidentification)
<i>University of Toronto</i>	
Department of Computer Science	R.M. Baecker
Department of Electrical Engineering	J.D. Lavers, P. Ratnam, W.M. Snelgrove
<i>University of Victoria</i>	
Department of Chemistry	R.N. O'Brien
<i>University of Waterloo</i>	
Department of Chemistry	M.J. Chong, T.E. Gough, L.W. Reeves, M. Tchir
Department of Civil Engineering	D.E. Grierson
Department of Computer Science	J.I. Munro
<i>University of Western Ontario</i>	
Department of Physics	E. Brannen
<i>University of Windsor</i>	
Department of Chemical Engineering	D.C.R. DeKee
<i>York University</i>	
Department of Chemistry	S.V. Filseth

Appendix D

NSERC List Tables

Table 1

Analysis of NSERC data by grant type

Program	Type	No. of Grants	No. of Individuals	Total Funding (\$000)
Operating	all	489	400	18,297
	equipment	44	44	4,555
	infrastructure	30	27	1,596
Strategic	all	102	83	7,454
	equipment	11	11	704
UIP	all	66	66	7,982
	CRD	44	44	3,893
	IRD	22	22	4,089
Total		657	551	33,733

Source: J. Porock, 'Funding of Research in Advanced Materials and Technologies through NSERC, 1984/85-1987/88', Natural Sciences and Engineering Research Council of Canada, 1988.

Table 2

Projects identified by NSERC as being 'peripheral' to AIM

Program	Type	No. of Grants	No. of Individuals	Total Funding (\$000)
Operating	all	164	137	6,052
	equipment	19	19	1,727
	infrastructure	7	7	625
Strategic	all	27	22	1,863
	equipment	2	2	56
UIP	all	18	17	2,155
	CRD	12	11	1,239
	IRD	6	6	916
Total		209	176	10,070

Source: *Ibid.*

Table 3

Total less "peripheral" (Table 3 - Table 4)

Program	Type	No. of Grants	No. of Individuals	Total Funding (\$000)
Operating	all	324	263	12,243
	equipment	25	23	2,828
	infrastructure	23	20	971
Strategic	all	75	63	3,591
	equipment	9	9	648
UIP	all	48	48	3,827
	CRD	32	32	2,654
	IRD	16	16	3,173
Total		448	374	23,663

Table 4

Analysis of NSERC data by grant code

Code	Operating Program		Strategic Program		UIP Program		Number of Grantees
	# Grants	\$(000)	# Grants	\$(000)	# Grants	\$(000)	
CEB	19	620	9	503	1	35	18
COA	70	2,788	11	620	10	879	60
COM	51	2,640	9	689	3	183	46
FIB	52	2,298	13	940	4	703	47
LIQ	12	263	0		0		11
MET	70	2,726	22	1,961	13	1,266	73
PHO	4	51	4	224	0		6
POL	62	2,187	10	711	9	874	59
ROB	79	1,796	17	1,282	14	1,535	93
SEM	69	2,879	7	524	13	2,551	68
Total	488	18,248	102	7,454	67	8,021	481

Table 5

Peripheral projects by grant code

Code	Operating Program		Strategic Program		UIP Program		Number of Grantees
	# Grants	\$(000)	# Grants	\$(000)	# Grants	\$(000)	
CER	0		0		0		0
COA	0		0		0		0
COM	15	524	2	99	0		14
FIB	19	630	5	327	1	316	19
LIQ	0		0		0		0
MET	25	1,063	6	390	5	488	25
PHO	2	21	0		0		2
POL	16	535	3	149	0		13
ROB	48	1,095	8	666	6	824	50
SEM	13	767	3	232	3	432	17

Table 6

Geographical distribution of NSERC funds

Province	Number of Grantees	Number of Grants	Total Funding \$(000)
British Columbia	46	71	4,377
Alberta	26	34	1,271
Saskatchewan	7	9	592
Manitoba	18	22	865
Ontario	211	272	14,155
Quebec	114	214	9,659
New Brunswick	10	12	809
Nova Scotia	8	10	295
Newfoundland	4	5	97

The Author

J.M. McIntosh is a Professor of Organic Chemistry at the University of Windsor. He graduated from Queen's University in Kingston in 1962 with a BSc in Chemistry. In 1966, he obtained a PhD in Organic Chemistry from the Massachusetts Institute of Technology under the direction of Professor A.C. Cope. Following a two-year postdoctoral appointment at the National Research Council and the University of Waterloo, he joined the faculty of the University of Windsor.

Professor McIntosh's scientific interests lie in the area of organic synthesis, particularly in the pharmaceutical area. He and his research group are the authors of over 50 refereed papers in the chemical literature. This report was researched and prepared during the course of a sabbatical leave.

The Centre for Resource Studies

The Centre for Resource Studies (CRS) was established in 1973, under the sponsorship of Queen's University, the federal Department of Energy, Mines and Resources (EMR), and The Mining Association of Canada (MAC), to carry out a program of research and publication on mineral policy issues.

The Centre provides opportunities for multidisciplinary research in resource studies at Canadian universities, furnishes reliable information on matters related to mineral resource policy, and promotes closer liaison between government, industry and other concerned groups. The research program is carried out both at the Centre and by means of contracts with qualified investigators, usually at Canadian universities. Small exploratory studies are also funded, through a system of grants-in-aid of research. CRS Seminars involve representatives from governments, industry, universities, labour and other interested groups in working sessions on issues of current concern. Through this program of research and seminars, and the resulting publications, the Centre contributes to informed discussions and a better understanding of significant issues.

The Centre is governed by a board of directors which establishes general policy and priorities for research. The board has sixteen members, appointed by Queen's University, The Mining Association of Canada, and the federal government. Guidance on the research program, together with discussion of policy issues and other matters, is provided by the Advisory Council. This body comprises all researchers associated with the Centre, together with members appointed from such groups as governments, industry, labour, and other interests. A Research Advisory Committee aids in the development of projects and the selection of research proposals. The executive director and staff are responsible for the work of the Centre within this framework.

Most of the funding for the Centre activities is provided by two of the sponsors, EMR and MAC. In addition, the Centre accepts contracts from other organizations interested in mineral policy research.

The Centre welcomes comments on its publications, proposals for research projects or for publication, or enquiries about any aspect of its work.

For further information, contact:

Centre for Resource Studies
Queen's University
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